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APRIL 1927

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American Institute of Electrical Engineers

COMING MEETINGS

ANNUAL BUSINESS MEETING, New York, N. Y., May 20

SUMMER CONVENTION, Detroit, Mich., June 20-24

PACIFIC COAST CONVENTION, Del Monte, Calif., September 13-16

REGIONAL MEETINGS

Middle Eastern District No. 2, Bethlehem, Pa., April 21-23

Northeastern District No. 1, Pittsfield, Mass., May 25-28

MEETINGS OF OTHER SOCIETIES

The American Physical Society, Washington, D. C., April 22-23

National Electric Light Association

Southeastern Division, New Orleans, La., April 26-29
Nebraska Section, Grand Island, Neb., April 27-28
Middle West Division, Topeka, Kansas, May 18-20

American Electrochemical Society, Philadelphia, Pa., April 28-30

The American Society of Mechanical Engineers, White Sulphur Springs, May23-26

Canadian Electrical Association, Niagara Falls, Ont., May 25-27

National Electric Light Association, Atlantic City, N. J., June 6-10

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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The Work of the Standards Committee

On June 26, 1899, the Institute accepted the report of its first Committee on Standardization. The original "Rules" may be found in volume sixteen of the TRANSACTIONS, covering but thirteen pages. The original committee consisted of seven members. It was appointed some time after a meeting held in New York on the evening of January 26, 1898, to discuss the standardization of generators, motors and transformers.

In the discussions the difficulties and advantages of standardization were emphasized, and the method of selection and personnel of the proposed committee received considerable attention. It was pointed out that there were three sides to the problems of standardization,—the manufacturer, the purchaser and the consulting engineer. The discussion is most interesting and instructive in the light of nearly 30 years of endeavor by the Standards Committee, as a continuing body with precedents and traditions now well established, to maintain friendly relations with manufacturers, to see to it that all interests are given an opportunity to cooperate, and to define terms and establish methods. It is interesting to note that the first committee, consisting of Professor Crocker, Chairman, and Messrs. Hutchinson, Kennelly, Lieb, Steinmetz, Stillwell and Thomson, was broadly representative of the industry. "There were giants in those days," and the fundamental ideas and principles originally discussed and formulated have been very generally adhered to in the continuous series of revised rules that have been issued.

The membership of the Committee was increased from time to time and its organization grew more complex, in an endeavor to have the Committee the better reflect the most generally accepted American electrical engineering practise. Through the organization of the United States National Committee of the International Electrotechnical Commission twenty years ago, the Standards Committee was brought into very close contact with international electrical standardization efforts. The rules of the International Electrotechnical Commission have been printed with the Institute's standards for some time. It is not too sweeping a statement to say that much of the high standing of the Institute as a professional society and the favorable opinion held of it by electrical engineers throughout the world, are in no small degree due to the unselfish and painstaking efforts of the members of the Standards Committee for more than a quarter of a century. Few contracts for electrical apparatus and equipment have been made in the United States and Canada in which reference to the Institute Standards will not be found. Fourteen sections of the Standards, now being issued in parts, have been translated into the Spanish language by direction of the Board, and permission has been given for translation into the Russian language.

In the nine or ten revisions of the Standards that have been issued, the Institute has recorded and codified the known facts and generally accepted practise lying within the field of the Standards Committee at the times of revision. As some one has said, the various editions have represented partly the knowledge of the time, partly the knowledge of the past. This must always be true in engineering standardization, and is a partial answer to a criticism frequently made that standardization tends to retard progress.

When the revision of the edition of the Standards published in 1922 was undertaken, it was decided to issue standards on particular subjects and in separate publications. The Standards Committee was reorganized by the Board, and a plan for carrying forward the work through "working committees" on particular subjects was instituted, with the definite provision that non-members of the Institute, specialists and experts, could be appointed on the working committees. A closer cooperation between the Technical Committees and the Standards Committee was also established. Under this plan, twenty or more separate Institute Standards have been prepared and approved by the Board, and most of them have been submitted to the American Engineering Standards Committee for approval as American Standards. Here difficulties have arisen, and very few of the Institute Standards have been approved as American Standards.

Vigorous steps are now being taken to reorganize the personnel and procedure of the Standards Committee, as expressed by President Chesney in his opening address to the Winter Convention on February 7, 1927, so to broaden the policy and methods in standardization work as to make standardization by the Institute, the major professional organization in the electrical field, meet with the fullest cooperation and participation of all electrical commercial and trade associations.

J. FRANKLIN MEYER

Chairman Standards Committee.

Some Leaders of the A. I. E. E.

Michael Idvorsky Pupin, thirty-eighth president of the Institute, (1925-26), was born at Idvor, Banat, Hungary. He was sent at an early age to the village school, but displayed such unusual talent that he was transferred to Prague, Czechoslovakia, preparatory for higher education. America attracted him, however, and he ran away from Prague and landed in New York in 1874. In the course of five struggling years he saved sufficient from such earnings as an unskilled boy could command to enter upon a course at Columbia College and in 1883 he was graduated with high honors and a B. A. degree. He then returned to Europe for the purpose of graduate work in physics and mathematics at the University of Cambridge, England, and the University of Berlin, Germany, obtaining from the latter his Ph. D. Again coming to America, he returned to Columbia College where, in 1889, he and Professor F. B. Crocker inaugurated the Electrical Engineering Department, Doctor Pupin acting as instructor in mathematical physics. In Berlin, his principal study had been physical chemistry, but owing to the newness at that time of this science in the American universities, it was not deemed practical to pursue it at Columbia and he turned his attention to researches in electrical science. His earliest work was to study the passage of electricity through rarefied gases, the outcome of which research was the subject of several papers by him. In 1892, he took up the subject of electrical resonance and electrical tuning and its application to resonance analysis of alternating currents. A patent for electrical tuning circuits by means of variable inductance and variable capacity was granted to Doctor Pupin and sold to the Marconi Company in 1902; in fact, the expression "electrical tuning" now universally in use originated with Doctor Pupin. He was also the first to produce an x-ray photograph in this country, as a guide to surgical operation. This was in January 1896, and at that same time he invented a method of rapid x-ray photography, by placing a fluorescent screen between the patient and the photographic plate, thereby shortening the time of exposure to a fraction of a second, notwithstanding the fact that a soft x-ray tube was used. In the course of this work he also discovered secondary x-ray radiation produced by the impact of primary x-rays upon solid conductors as well as non-conductors. This secondary x-ray radiation is today employed in the study of x-ray spectra.

It was Doctor Pupin who first solved the mathematical problem of electrical transmission over telephone wires with inductance coils periodically recurring at various points. By this was formulated the rule that such a conductor acts as a uniform conductor for all frequencies for which there are several conductors per wavelength. The solution of this problem led to the construction of the so-called loaded telephone conductors, or, *Lignes Pupinize*, as they are known in Europe. Such conductors, aided by vacuum tube repeaters, are now employed in this country, as well as in Europe, for the purpose of uniting distant centers of population into one telephonic community by means of loaded telephone cables. Distance is no longer a barrier to telephonic communication. The toroidal coil, suitably laminated, is employed in the construction of these cables, and these represent another problem first solved by Doctor Pupin and for which personal patent was granted later serving as a basis for further development work performed by the Western Electric Co. in this country and the Siemens und Halske in Europe. The advisability of rectification in wireless reception was first suggested by Doctor Pupin and the first apparatus capable of producing rectification was his electrolytic rectifier (1899). Other types of rectifiers, particularly the vacuum tube type, have subsequently been developed and today rectification forms one of the pillars of the radio art.

The mathematical theory of artificial lines of every kind, (known today as networks), was a development of Doctor Pupin's in 1899 and forms the mathematical basis for the construction of present day electrical filters. Negative resistance, also original with him, was first produced by means of an induction motor run beyond synchronism. It was found that by generating such resistance in a circuit containing inductance, capacity, and resistance, the circuit became highly resonant; in fact, continuous electrical oscillations were produced in this way. E. H. Armstrong, a pupil of Doctor Pupin, obtained this negative resistance by means of a three-electrode vacuum tube oscillator and patents for its application were granted him and Doctor Pupin and sold to the Westinghouse Company November 1920.

The subject of electrical wave transmission over long conductors began to occupy Doctor Pupin's attention as early as 1894; his earliest work in this direction was chiefly mathematical. It was he who found a general solution of the great problem of LaGrange; namely, analyzing the motion of a stretched, weightless string, carrying at equal intervals of its length, equal masses. The solution of this purely dynamical problem immediately suggested its applicability to transmission of electrical waves over telephone wires. It was obvious that the introduction of suitable inductance coils at predetermined distances along the telephone line would greatly improve the efficiency of transmission by making it possible to transmit the electrical energy carrying the articulate voice of man by high potential and small current, thus reducing ohmic resistance losses on the line. This invention was acquired by the American Tel. & Tel. Co., January 1901.

Doctor Pupin is very proud of the fact that in the course of his academic career he had for his pupils such men as Dunn, Millikan, Langmuir and Armstrong. Also during his academic career he was the recipient of some fourteen honorary degrees from various American universities, several gold medals and the Hebert Prize of the French Academy.

A-C. Elevator Motor Drive

BY E. B. THURSTON[1]

Fellow, A. I. E. E.

Synopsis.—*There are very few data available on the problems of using alternating current when applied directly to a motor on an elevator. It is apparent, also, that eventually there will be no d-c. power transmitted for elevator service.*

Because of these facts and the size of this industry it seems that such data should be available. A paper covering the entire field in detail would be excessively long and it is therefore the aim of this paper to cover the subject in a general way, giving such outstanding facts as are felt to be of most interest at this time.

It is hoped also to correct a false impression that is sometimes found to exist—that an a-c. elevator is not practical for car speeds above 350 ft. per min. Without question, this understanding was correct six or seven years ago but it is desired to call attention to the fact that for the past five years many a-c. elevators have been installed with car speeds in excess of 500 ft. per min. and today some are operating as high as 700 ft. per min., and nothing has appeared to indicate that there is a limit of car speed other than for any other type of control.

A brief outline of the necessary requirements of the elevator machine is given because as yet the development of a-c. elevators has depended upon the success of this unit.

The desirable characteristics of the motor are given somewhat in detail, the important ones being positive speed control, elimination of exposed and sliding contacts, speed ratios of at least 6:1, a rotor of low kinetic energy, quiet under operation, allowing torque characteristic changes, smooth control of speed changes, liberal temperature range, high power factor, a maximum torque capacity and maximum practical starting torque per ampere.

The desirable characteristics of the controller which permit high speed elevator operation with economical and reliable service and a minimum number of shut-downs, may be outlined as follows: Full magnetically operated but with a minimum number and types of magnets, types of magnets that guarantee against magnetic hum or chatter requiring no oil immersion and giving a constant pull. The controller parts in general should be as interchangeable as practical, with oilless bearings and a minimum of auxiliary parts and contacts. As a whole, the controller and its wiring must be simple and easily understood.

The principles of control allowing the high-speed elevator operation are rapid but smooth acceleration and retardation, a forced slowing down of the elevator by the motor irrespective of the operator and allowing the simultaneous or overlapping braking action of the slowing down and stopping means.

The brake magnet must be one guaranteeing against magnetic hum or chatter, giving a constant pull, and must be positive and rapid but not violent in action.

The curves which were taken by power companies serve to show the high power factor and a minimum of line disturbance.

Introduction

Statistics show that the elevators of the larger cities actually carry more passengers than the horizontal transportation systems. Furthermore, there is probably no industry so vital to the public and of corresponding size with its equipment and principles so little understood by the engineering profession. Naturally they are justified in asking for more reliable data.

Referring to published papers on elevators, we find there are a few on elevator service, d-c. elevators, etc., but without question there is need for more information on these and similar subjects. Upon searching for papers with information about a-c. elevator equipment, its history and problems, it is found there are so few available that it would be very difficult to get a fair understanding of this phase of the industry.

Far from a general understanding of the present art of a-c. elevators, we hear such expressions as these: "They are all right for low-speed elevator service;" "They cannot be operated smoothly;" or, "A-c. magnets and motors are too noisy to use for passenger service." These and similar expressions serve to show that it is easy to forget that new developments are possible.

Today, it has been proved illogical in connection with any development to say "It cannot be done," although this statement has been made in connection with high-speed a-c. elevators.

When we stop to realize the tremendous change from direct to alternating current in general applications, and other developments that have been made in recent years, it is natural to expect that the elevator industry have progressed accordingly. It is felt, however, that this industry did not keep pace with developments in general previous to 1920, with the result that since that time the developments have been tremendous, especially with alternating current, in order to bring this industry to its present state.

The fact that passenger a-c. elevators are operating at 700 ft. per min. and have been proved practical and reliable should make information regarding their development interesting to electrical engineers.

It is not the purpose of this paper to cover the subject in detail but rather to give a general discussion of the more important problems with the hope that other papers with more detail will follow.

History

About 20 years ago there was developing a demand for direct-connected a-c. elevators, especially from many of the larger manufacturing concerns. This was due to their plants operating on alternating current and to the production basis of manufacturing.

A large percentage of this demand was for the higher capacity with car speeds of 100 to 200 ft. per min., which at that time was considered high speed for freight service. This presented many problems that had not been met before.

The single-speed, slip-ring type of motor, being the only one considered practical for elevator service, was

1. Haughton Elevator and Machine Co., Toledo, Ohio.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

used and proved quite satisfactory for the demands of service at that time. Due to continual starting, stopping, and reversing, the major problems were those of preventing the rotor working loose and the burning and rapid wearing of the slip-rings.

The brake problem was considered the most serious and difficult. Many devices were developed with none having all the desired features.

The mechanically operated brakes gave the best operating service but were not by themselves considered safe. The magnet-operated brakes were very violent in action and noisy. A brake that proved quite popular and reliable was a dual type, using the mechanically-operated principle for the service and a magnetic-operated emergency brake for safety.

At this time a-c. elevator controllers were mostly mechanically operated, magnetically-operated controllers not having been developed to a reliable stage.

About 15 years ago the high resistance squirrel-cage motor began to find favor and was used for service requiring the lower horse powers. This type of motor at first met with considerable opposition, probably more because of its name than any other one thing, although there were many motors of this type manufactured with characteristics such that objections to their use were well warranted.

At this time these squirrel-cage motors were started directly across the power lines, requiring only a very simple controller, with the result that an elevator of this type was found to be the most reliable obtainable.

Its operation limited its application, however, because of the high instantaneous starting current drawn from the line, and its too sudden starting of the car. It is now apparent that to have added a resistance starter or its equivalent would have overcome these objections, but we must not forget that at that time one of the chief objections to the slip-ring type of motor was that it required a starting device, and there was no real satisfactory and reliable magnetic starter available for elevator service. Thus the high-resistance, squirrel-cage motor across the line elevator gained its reputation for reliability.

About 10 years ago the fact was apparent that the a-c. elevator for all car speeds and service was inevitable. While passenger elevators were at this time available for car speeds up to 300 ft. per min., they could not be considered as satisfactory for reliability, smoothness and noise. It was necessary, therefore, to plan for a large amount of research and development work.

The equipment offered at this time generally used a 3:1 motor speed ratio and a motor composed of a single stator and rotor with slots sufficiently large in each to permit two insulated and independent windings. This required not less than five slip-rings. Although it is difficult to accelerate a slip-ring motor smoothly and rapidly with varying loads, it is even more difficult to retard from a higher to a lower synchronous speed, smoothly. It was also found impossible by any known method to reduce the motor noise sufficiently to make it satisfactory for all elevator service.

Experience indicates that it is impossible to accelerate an elevator at high speed with a slip-ring motor rapidly and smoothly with varying loads except by what might be called a dual acceleration.

Let us suppose that we have an elevator fully loaded; to accelerate it in the up direction will require approximately the maximum torque available and a controller resistance may be used that produces maximum torque at standstill. This resistance may be cut out by any known method, either series relay, speed control or definite time, and this operation will be satisfactory.

When starting the fully loaded elevator in the down direction, however, the load is tending to drive the motor in that direction and its maximum torque added to the load tendency to start gives too violent an action, so it is necessary to use additional resistance for a smooth start under all loads. With this additional resistance it is impossible to utilize the full available torque of the motor when used in connection with the series relay or speed control method of acceleration.

If we now use a definite time control for acceleration, it must be set slow in order to lift full load and not short circuit the resistance too rapidly, causing the motor to stall. This results in too slow an acceleration when lifting load, if the resistance is such as to give smooth operation when lowering the load. The only way found to insure the desirable results was by the use of a rapid definite time control acceleration for all surplus resistance down to that which produces maximum torque at standstill and from this point by series relay or speed control.

With this type, it was found that with fairly rapid and smooth acceleration it was possible to insure lifting a 25 per cent greater load with a given motor.

This, however, increased the cost considerably, made the controller more difficult to keep in adjustment, and still used slip-rings.

During the next five years there were what might be termed radical developments, the results of which allowed the installation early in 1922 of the first a-c. elevators running above 500 ft. per min.

With these developments and further experience the range of speed has been raised to 700 ft. per min.

Definition of A-C. Elevator

In order that there may be no misunderstanding as to the type of equipment considered when the term, a-c. elevator, is used, it should be defined as an elevator with alternating current applied only directly to the elevator motor, controller and brake with no conversion.

Machine

In the development of a-c. elevators for the higher car speed service, there were four vital units to be con-

sidered, each a complete problem by itself—the machine, the motor, the controller and the brake.

It was immediately apparent from known principles of a-c. motor construction that a suitable geared elevator machine designed for the high car speed service must be produced before much headway could be gained with the other units.

It was not, nor is it now, practical to produce a gearless type, a-c. motor that is satisfactory for elevator service. The geared type elevator machine for the higher car speed service had been more or less neglected because a gearless type d-c. motor had been developed for this class of service.

It soon became evident that the geared elevator machines, designed primarily for the slower car speed service, would have to be re-designed for the higher car speeds and would require refinements for passenger service that had not been available theretofore.

Some of these important refinements were; a more sturdy machine throughout, more accurate machine work especially in connection with the gear, anti-friction bearings for the thrust of the worm shaft, antifriction bearings for the drum shaft, and gears which would be perfectly adjustable under load and running conditions of the elevator.

The reason for the more sturdy machine and accurate workmanship is to reduce vibration that may produce noise objectionable for this class of service. The antifriction bearings are necessary to increase the efficiency and the adjustable gear to give the proper running position. As further explanation for the adjustable gear, it will be appreciated that it is impossible to babbitt a gear in place and insure having the correct gear tooth contact under operating conditions with the load of car and counterweights on the machine.

Inasmuch as the slower and moderate speed passenger elevators do not always warrant as high a degree of refinement as the higher speed passenger elevators, it is desired to confine the remainder of this paper to a-c. elevators with car speeds greater than 350 ft. per min.

The Motor

The a-c. motor being used today for the higher speed passenger service represents the result of the accumulated experience of the last 15 years. It has been a very gradual and conservative development.

It is at once evident that the motor must have more than one speed and these speeds must be positive and practically constant whether the motor is running as a motor or is driven as a generator. A direct-connected elevator motor is always required to operate under both conditions, and any motor which varies much in speed with load variations must be eliminated.

Accordingly, the induction type of a-c. motor is the only one that has been found suitable for elevator service and giving the positive multi-speed control.

As was stated in the history, the slip-ring type of induction multi-speed motor was preferred until about 1919 at which time the multispeed high resistance squirrel-cage motor was indicating advantages.

Past experiences gave a basis for arriving at what was essential for a motor in order to produce what would be considered a satisfactory a-c. elevator for all service and speeds. Tests indicated that so far as is known the single stator with two independent windings and a high resistance squirrel-cage rotor does fulfill more of the requirements than any other type available.

The more important of these requirements are outlined and explained as follows:

First, it must be practical to manufacture motors of at least 6:1 speed ratio and still have a motor of practical size to install on the elevator machine. As far as is known, 3:1 ratio was the maximum for slip-ring type motors. Squirrel-cage motors of from 25 to 150 h. p. with 6:1 ratio have been in regular elevator service for over five years.

Second, the motor must be as small as possible, especially the rotor. This is necessary in order to keep the kinetic energy at a minimum and allow rapid acceleration and retardation with a minimum of power consumption and starting current. It is apparent that the single stator squirrel-cage motor would be best fitted for this requirement.

Third, it must be possible to design a motor sufficiently quiet in operation to allow its use in hospitals, hotels, apartments, office buildings and private residences. Because of the insulated polar windings in the stator and the rotor, the slip-ring type of motor requires slot combinations such that it is impossible to reduce noise sufficiently, while the squirrel-cage motor allows practically any slot combinations.

Fourth, the motor must allow torque characteristic changes at the installation. This is necessary because it is practically impossible to determine the exact requirements in advance, and if it were possible, it would be impractical to design a motor for each application. These changes can be accomplished in either the slip-ring or squirrel-cage motors after the general motor characteristic requirements are known.

Fifth, the motor must allow a smooth and positive control of speeds, whether accelerating or retarding, and still not require an excessive number of switches or a complicated and expensive type of controller. This is necessary in order to obtain simplicity and reliability. As outlined in the History, the squirrel-cage motor is best suited for this requirement.

Sixth, all sliding and exposed contacts should be eliminated. This is very essential because of the operating conditions and requirements. It is a generally recognized fact that the squirrel-cage type of motor is the most reliable.

Seventh, the motor must have sufficient radiation to permit the handling of maximum elevator service without abnormal temperature rise. This is one of the most important problems of design in connection with

high-resistance squirrel-cage motors for elevator service. It is possible to change the heating of a motor on elevator service a large per cent by changing its characteristics. It should also be recognized that standard commercial motor parts cannot be adapted to all elevator service. One of the most important facts to consider when designing a motor for elevator service is that its average running speed is usually less than one-half its full rated speed. This results in less than one-fourth the volume of air that a constant running motor would have. And last its radiating surface must be carefully considered.

Eighth, it is very important to have a relatively high running and starting power factor. The reason for this is to reduce to a minimum the power line disturbance when starting or lifting maximum loads.

Ninth, a motor should be capable of producing the maximum starting torque that is practical to obtain with given mechanical dimensions. This is necessary in keeping the kinetic energy at a minimum and increasing the acceleration and retardation efficiency.

Tenth, the motor should produce the maximum practical torque per ampere in starting. What is meant by this is that it should produce the maximum starting torque obtainable without increasing the frame size. This is also necessary to obtain the most efficient acceleration and retardation. In this connection attention is called to the fact that it is more important to have efficient acceleration and retardation than efficient full speed operation in order to obtain the most economical elevator service. This fact is also very forcibly shown in connection with d-c. elevators.

Exhaustive tests under actual operating conditions were necessary to develop a motor that would give these requirements. The facts found by these tests resulted in the development of a new motor of entirely new characteristics and one that was very different from any commercial motor available.

Controller

Next to the development of this motor the important problem was the development of a controller that would give certain required characteristics and could be adapted to control this motor as required.

The important requirements for a satisfactory and reliablc a-c., high-speed elevator controller are outlined as follows:

First, it should be full magnetically operated. This is self-evident because it would not be practical to operate at high speeds with a mechanical control.

Second, it should have a minimum number of magnets. This is necessary for simplicity and reliability.

Third, the magnets should be interchangeable, as far as practical. This is essential for reliability and low maintenance.

Fourth, it is very necessary to insure continuously against magnetic hum or chatter. This is because of magnetic noise being so objectionable in connection with elevators. In view of this it seemed essential to use a polyphase magnet of a non-sealing type although this was a radial departure from previous practise.

Fifth, it was very desirable to use a type of magnet that did not require oil immersion, because oil around a controller has always been found objectionable.

Sixth, the magnets should be such as to give a constant pull throughout their range of action. This is necessary in order to eliminate auxiliary retarding devices and yet insure against too violent an action in closing the switches.

Seventh, to insure low maintenance and reliability in operation, the units, contacts and parts should be interchangeable to the extreme.

Eighth, all bearings should be oilless to prevent the collection of dust and to insure long life with a minimum amount of attention.

Ninth, experience indicates that a series or speed control of acceleration does not lend itself to elevator requirements; therefore a minimum number of dash pots or retarding devices should be used and, if dash pots, they should be large, sturdy and oilless to insure against variation in their retarding action under all conditions of service, care and atmospheric changes.

Tenth, there should be a minimum of auxiliary contacts. This is required to insure against frequent or long shut-downs, because experience has always proved that small or auxiliary contact troubles more often do not indicate themselves and therefore are very difficult to locate, the result being long interval shut-downs while locating the fault. Attention is called to the fact that it is not the cost of a replacement contact of an elevator as much as the time out of service, that is most important.

In the interest of reliability, then, there may be mentioned; sturdy construction, minimum number of magnets, minimum of auxiliary contacts, a minimum of power contacts for service rendered, and contacts that give long life.

After considerable research it was found that a polyphase rotating-magnetic-field rotary type of magnet would give the above requirements. It was found that using this type of magnet, however, would make the controller somewhat more expensive to manufacture than with other known types; nevertheless experience has proved that this increased first cost was more than justified by the results obtained.

Further, it is interesting to note that this type of magnet made possible other desirable features. It has inherent phase reversal protection, inherent phase failure protection, allows the locking of the switch contacts in the off position, allows the forcing open of contacts by power should they mechanically stick closed, or vice versa, and gives the car control switch control over two separate and independent circuits.

Incidentally, this type of magnet allows a very simple

system of wiring which is not what was originally anticipated.

Figs. 1 and 2 are front and rear views of a controller using this type of magnet, and show the simplicity of wiring and the interchangeability of parts.

Principle of Control

After the development of the controller, the next and probably the most vital considerations to decide were the principles of control.

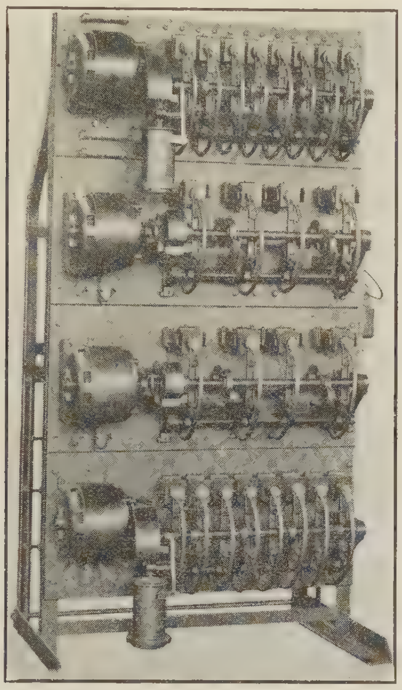

Fig. 1—Front View of A-C. Elevator Controller

It was evident that in entering a new field of application (because it is believed there were no a-c. elevators in operation with car speeds above 400 ft. per min., prior to 1920), there were many problems to overcome. The principal and most important one of these was safety, which led to conclusions that proved very important.

When it is desired to stop quickly, the neutral or reverse position of the car control switch should produce this result, or in other words when traveling at full speed and immediately moving the car control switch to the neutral or reverse position, all of the normal stopping means must act together. This principle was old with d-c. elevators but had never been available with a-c. elevators. This result or its equivalent is essential for smooth, rapid, positive and safe operation of a-c. elevators at the higher car speeds.

It will also be appreciated that this equipment has no run-away characterisitics, because there is no generator action from an induction motor when disconnected from the power line. Should the power fail, all devices will immediately return to the stop position regardless of the load, speed or direction.

It was also found desirable for the control to be such as to tend to increase the power factor of the motor, thereby aiding in reducing any line disturbance under operating service to a minimum. It is probably of interest to know that many of these elevators are operating very satisfactorily in buildings having a common transformer for lights and power, and experiencing no trouble from light flicker.

The Brake

It is rather generally understood that an elevator magnet brake is applied by a compression spring or by gravity and released and held released by a magnet while the elevator is operating.

The major problem is the development of a suitable a-c. magnet that will give reliable operation and still be such that it will be suitable for all classes of work. The important necessary requirements are outlined as follows:

First, it must insure against a magnetic hum or chatter under all conditions of service, such as low voltage, want of adjustment, collection of dirt, etc.

Second, it must be one that does not require oil immersion for cooling or reducing noise. Further objections to the use of oil immersion are its effect in varying brake operation with atmospheric changes and the liability of getting oil on the brake drum.

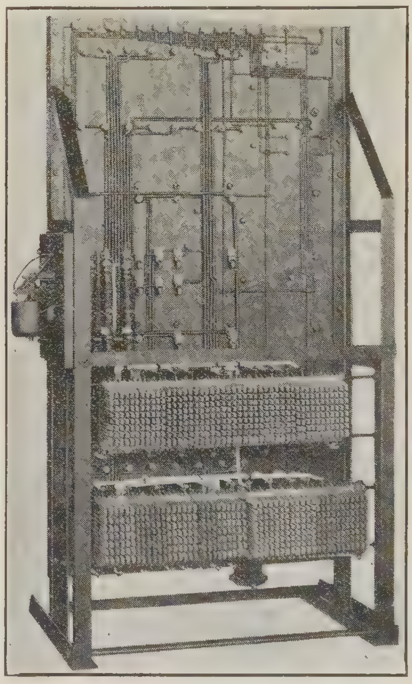

Fig. 2—Rear View of A-C. Elevator Controller

Third, it must insure against the violent action so common to a-c. magnets.

These requirements prompted the following: that it should be polyphase, non-sealing, giving a constant pull and be reciprocating in action.

After considerable research a magnet was developed that fulfilled all of the above features.

A sectional view of this magnet is shown in Fig. 3. Its principle of operation is the taking advantage of the end pull on a polyphase induction motor when the rotor is axially shifted out of line with the stator. This characteristic everyone is familiar with, and it is also generally known that the synchronous rotating magnetic field of such a motor is always constant.

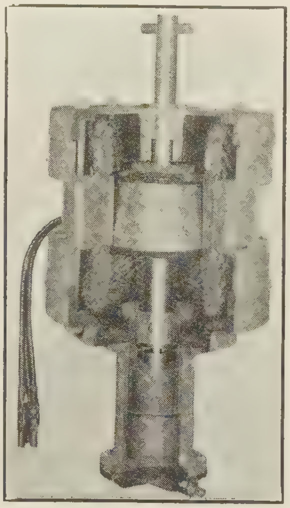

Fig. 3—Non-Sealing A-C. Brake Magnet

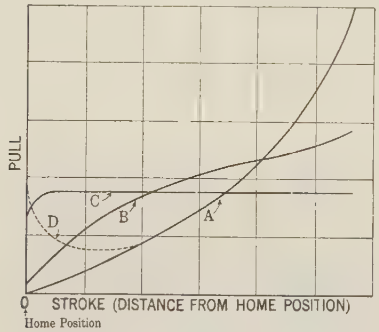

Fig. 4—Characteristic Curves of A-C. Magnets

Curves *A*, *B*, and *C* are for the rotating-field type of magnet. Curve *A* is for a cylindrical coil. Curves *B* and *C* are for tapered cores, Curve *C* being the most desirable design. Curve *D* is a characteristic of the ordinary a-c. magnet.

Now if only the rotor iron is used with no closed winding on the rotor, there will be little rotative action but the end pull action remains the same, and its value will be absolutely steady and entirely free from a cyclic vibration.

With a laminated core having a surface parallel to the axis, the end pull curve characteristic is as shown by curve *A* in Fig. 4. The abscissa of this curve is shown as inches of stroke or movement from the home position, shown at zero, with the extreme right hand end showing the position at which the core is about to leave the stator. The ordinates are shown as the end pull in pounds necessary to maintain any particular position or stroke.

It was found that the core surface can be tapered slightly and produce curve *B* and by a different tapering to produce a curve similar to *C* which was the desired characteristic curve for this particular application.

It should be remembered that other types of a-c. reciprocating magnets have a characteristic pull curve similar to curve *A* except that the lower or home position will follow curve *D*. With this it is seen that the magnet could not be required to operate and hold more than the lowest point of curve *D* and with the maximum as shown by curve *A* it inherently produces the violent action of a-c. magnets so familiar to electrical engineers.

Test Records

The following test records were taken at random from files and it is hoped they will prove of interest.

Figs. 5, 6 and 7 were traced from tests made by one of the largest power companies and are of an elevator rated for 1500-lb. capacity at 425 ft. per min. The

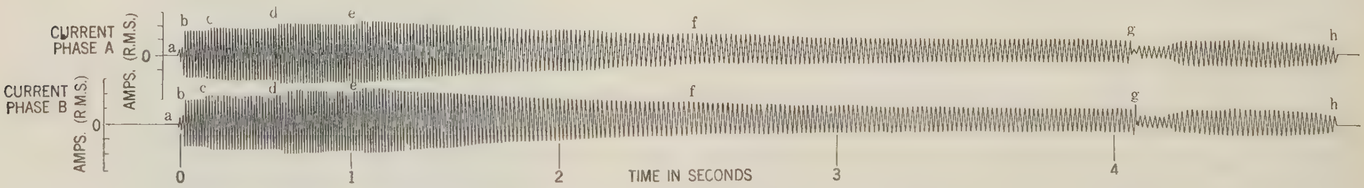

Fig. 5—Oscillogram Showing Current in A-C. Elevator Motor, Starting, Running and Stopping

Taken on an elevator rated 1500 lb. at 425 ft. per min, with a two-phase, 220-volt motor having 3:1 speed ratio. The elevator was run from the third to the fifth floor with 1000 lb. in the car. At *a* the motor was started on its low-speed connection. At *b* it was transferred to the high-speed connection. Positions *c*, *d* and *e* show respectively the closing of the first, second and third accelerating switches. At *f* the elevator is in full speed. Position *g* shows the transfer to low-speed connection and *h* shows the disconnection for stopping.

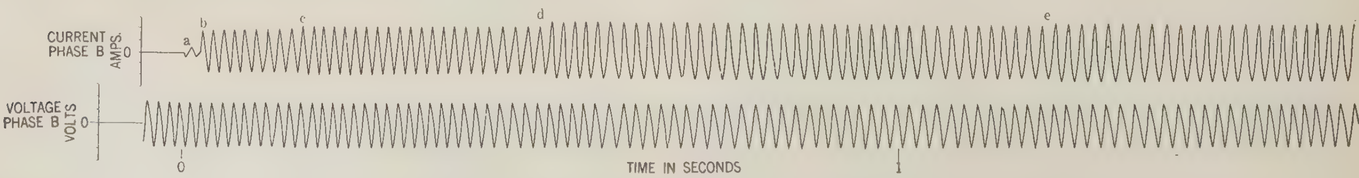

Fig. 6—Oscillograms Showing Elevator Operation with Overload

The conditions are the same as those in Fig. 5 except that the car carried 2000 lb., an overload of 33 per cent.

motor is a 3:1 speed ratio, 220 volts, two-phase. Fig. 5 is an oscillogram showing the amperes in each phase with time in seconds as abscissa. In this particular operation the elevator was run from the third to the fifth floor with 1000 lb. in the car. Starting from the left at zero time, position *a*, the motor was connected

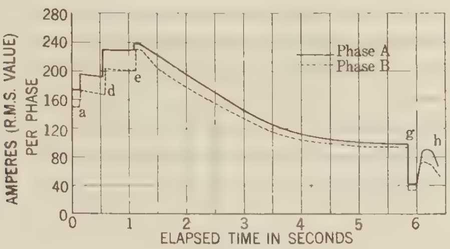

FIG. 7—CURRENT CURVES OF ELEVATOR LIFTING OVERLOAD

The load is 2000 lb. The points *c*, *d*, *e*, *g* and *h* correspond to similar points in Figs. 5 and 6.

for its low speed. Position *b* shows the current on transferring to the high-speed connection. Position *c* shows the closing of the first accelerating switch. Positions *d* and *e* show the closing of the second and third accelerating switches. Position *f* shows that the elevator has attained approximately full running speed and that this has taken place in 2½ sec. Position *g* shows the transfer to low speed for slowing down or stopping and position *h* shows the point where motor was disconnected for stopping, thus completing a two-floor travel in less than five sec.

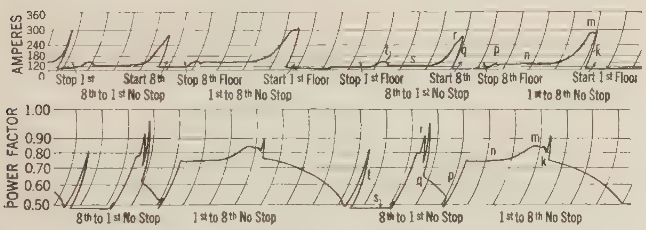

FIG. 8—PERFORMANCE CURVES OF ELEVATOR IN FULL RUNS FROM FIRST TO EIGHTH FLOORS

Elevator is rated 2500 lb. at 510 ft. per min. with a three-phase, 220-volt motor with 4:1 speed ratio. The motor carried 2031 lb. Position *k* is starting upward; *m*, accelerating upward; *n*, running full-speed upward; *p* slowing and stopping after upward run. Point *q* is starting downward; *r*, accelerating downward; *s*, running full-speed downward; *t*, slowing and stopping after downward run.

Fig. 6 shows oscillograms of the voltage and current in one phase with *a*, *b*, *c*, *d* and *e* representing the same positions as shown in Fig. 5, but with a more rapid time scale and lifting a load of 2000 lb. in the car. It should be noted this is an overload of 33 per cent.

Fig. 7 is a curve plotted by the power company from an oscillogram of the amperes in each phase while the elevator is operating from the third to the fifth floor with a load of 2000 lb.

Figs. 8, 9 and 10 were taken by another large power company and are curve-drawing instrument records; they are to be read from right to left. This elevator has a rated capacity of 2500 lb. at 510 ft. per min., the motor being a 220-volt, three-phase and having a 4:1 speed ratio. The same letter on each curve represents the same operation in all three figures. Position *k* is the point of starting in the up direction, *m* is accelerating in the up direction, *n* the full speed running in the up direction, *p* the slowing down and stopping in the up direction, *q* the point of starting in the down direction, *r* is accelerating in the down direction, *s* the full speed running in the down direction and *t* the slowing down and stopping in the down direction.

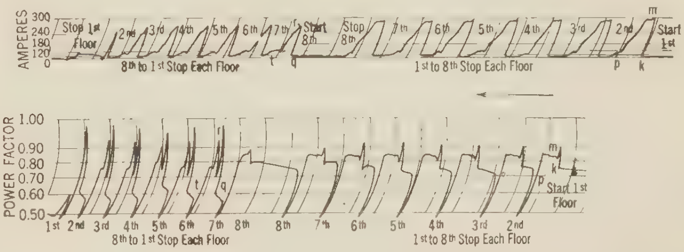

FIG. 9—ELEVATOR PERFORMANCE STOPPING AT ALL FLOORS

Elevator, load and notations are the same as in Fig. 8

It should also be noted all these tests were with a load of 2031 lb.

Fig. 8 shows full runs between first and eighth floors, the upper curve being for amperes and the lower one for power factor.

Fig. 9 shows full runs between first and eighth floors but stopping at all intermediate floors.

It is understood that this installation in actual service is showing an average power factor in excess of 80 per cent.

Fig. 10 is of particular interest because it shows the effect on the current when the elevator is traveling at full speed in each direction and an instantaneous full reverse movement of the car control switch is made.

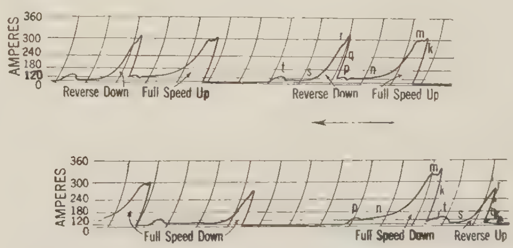

FIG. 10—EFFECT OF REVERSING ELEVATOR WHEN RUNNING AT FULL SPEED

Elevator, load and notations are the same as in Fig. 8

Without giving detail thought to the matter, there has been a general impression that an a-c. elevator motor does not return power to the line as a generator when the load is tending to drive it above its synchronous speed. In order that this impression may be corrected, it is found from experience that on elevators with car speeds from 400 to 700 ft. per min., the motor will supply the controller and brake losses and in addition return from 25 per cent to 40 per cent of its rated h. p. back to the power line as a generator.

Theory of Action of the Induction Watthour Meter and Analysis of its Temperature Errors

BY D. T. CANFIELD[1]

Associate, A. I. E. E.

Synopsis.—*The question of changes in the registration of watthour meters due to variations in temperature is receiving considerable attention at the present time from manufacturers and public utilities alike. This paper discusses the development of a temperature-compensated watthour meter. The effect of certain changes in the fundamental constants of the meter circuits and the materials of certain vital parts are shown to point out the necessity of two independent compensating devices.*

The compensating devices found most effective consist, first, of a permanent magnet flux diverter mounted on bimetal strips in such a way that it shunts more or less of the permanent magnet flux around the disk, on a decrease or an increase in temperature, respectively, and second, a moving lag plate controlled by bimetal strips arranged in such a way as to cause the plate to move up or down with an increase or a decrease of temperature, respectively.

In Appendix I is given the construction of a theoretical vector diagram of an induction type watthour meter showing the relative phase positions of the various fluxes, voltages and currents that are present.

In Appendix II is given a discussion of the sources of temperature errors in watthour-meters as derived from an analytical study of this diagram.

An attempt is also made in this paper to summarize these sources, the reason for their existence, and their effect upon the registration of the meter, in convenient tabular form.

* * * * *

Introduction

The interchange of large blocks of power between utilities, the need for accurately determining water rates of turbines, and the increasing number of consumers who use large amounts of energy, are making various refinements in watthour meter practise desirable. In loads of this character, any real increase in precision is more than desirable.

As a natural consequence, it follows that the task of developing a temperature compensated watthour meter is typical of the problems to which American meter manufacturers are devoting their attention. Moreover, the study of temperature errors in watthour meters is in line with the suggestions made by the subcommittee on Instruments and Measurements of the American Institute of Electrical Engineers.

The writer was engaged to investigate the effectiveness of temperature compensation by thermostatic control of the lag adjustment and drag element of a watthour meter.[2]

At the time the solution of this problem was undertaken, very little of a definite nature was available in the literature of the art concerning the real sources of the change in registration of watthour meters, due to changes in ambient temperature. Subsequently, however, there appeared a very excellent discussion and classification of these sources by Messrs. I. F. Kinnard and H. T. Faus.[3]

Since a complete understanding of the action of the compensating devices later to be described is contingent upon an equally complete understanding of the sources of the errors they compensate for, it will not be out of place to repeat a similar classification and discussion in this paper.

Table I gives a summary of such a classification and discussion. This table was derived from a theoretical analysis of the vector diagram of Appendix I, the discussion given in Appendix II, and a study of the registration curves of meters at different temperatures.

Determination of the Resultant Effect of Group I Errors

Since in Group I there are some effects producing an increase in speed and others producing a decrease in speed, it is necessary to determine the resultant effect of Group I errors as a whole. To do this, a set of typical performance curves was obtained, such as those shown in Fig. 1. These curves are the per cent registration curves of a watthour meter under different temperatures and lagging power factors. They were obtained

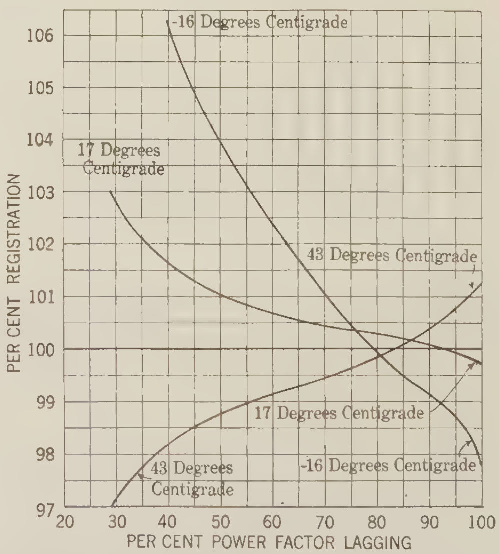

Fig. 1—Typical Performance Curves of an Uncompensated Meter, at Lagging Power Factors

1. Assistant Professor of Electrical Engineering, Purdue University, Lafayette, Indiana, and Consulting Engineer for Duncan Electric Mfg. Co.

2. Developed by Mr. Jesse Harris, Chief Development Engineer of the Duncan Electric Manufacturing Company.

3. Trans. A. I. E. E., 1925, p. 275.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

TABLE I

A SUMMATION OF THE SOURCES OF ERRORS IN WATTHOUR METERS DUE TO VARIATIONS IN TEMPERATURE AND THEIR EFFECT UPON REGISTRATION

Combination I—Assumes an increase in ambient temperature with lagging power factor

Group	Error	Description of error	Effect on meter speed	Effect of decreasing power factor	Reasons for the changes in speed
	1	Changes in the magnetic properties of the permanent magnet.	Increases	Independent	Decrease in permeability, reluctance increases, dragging flux decreases, meter speeds up.
	2	Changes in the magnetic properties of the magnetic circuits of the potential and current elements.	Decreases	Independent	Decrease in permeability, reluctance increases, driving fluxes decrease, meter slows down.
I	3	Changes in length of the air-gap of the permanent magnet.	Decreases	Independent	Magnet gap widens, causing the flux passing between the gap to decrease. Meters using this flux for dragging will speed up, while meters using a shunted portion of this flux will slow down.
	4	A shift in the phase position of the exciting current.	Increases	Independent	The exciting current shifts down due to decreased iron losses, causing a shift in I_p R_1 This in turn increases E^1 which must be accompanied by an increase in Φ. (See Fig. 12.)
	5	An increase in the magnitude of the exciting current.	Decreases	Independent	Increase in reluctance of iron cuts down Φ, exciting current then increases but not enough to increase Φ to its original value. This means a decrease in E^1 and therefore in the speed of the meter.
I	6	Changes in the choking effect of the lag and light-load plates .	Increases	Independent	The choking effect of these plates upon the main flux decreases. More of the main flux acts as a driving flux. Meter speeds up.
	7	Changes in the resistance of the potential windings.	Decreases	Independent	Shift of I_p R_1 due to shift in exciting current causes E^1 to decrease and consequently Φ. Speed decreases.
II	8	Changes in the resistance of the potential windings.	Decreases	Increasingly	Reacts to decrease the 90 deg. relation bietween the driving fluxes. Speed decreases.
II	9	Changes in the phase position and magnitude of the exciting current.	Decreases	Increasingly	Both effects, shift the voltage V^1 (See Fg. 12). so as to decrease the 90-deg. relation between the driving fluxes. Speed decreases.
	10	Changes in the resistance of the lag and light-load plates.	Decreases	Increasingly	Increase in resistance of these plates decreases the 90-deg. relation between the driving fluxes. Speed decreases.
	11	Changes in the resistance of the disk.	Decreases	Increasingly	Reacts to decrease the 90-deg. relation between the driving fluxes. Speed decreases.

by comparison to another watthour meter kept at a constant temperature. In all these curves the potential coils were left excited continually and the current coils warmed up for a reasonable time prior to checking. As a result, the errors caused by self heating are negligible so that the change in registration is due solely to a change in ambient temperature.

As seen by the 100 per cent power-factor points of the curves of Fig. 1, the resultant effect of Group I errors is to speed the meter up on an increase in temperature. This means that errors No. 2, 3, 5, and 7 are small in the aggregate compared to the combination of No. 1, 4 and 6. Fig. 1 also shows that as the lagging power factor decreases, the meter slows down at high temperatures and speeds up at low temperatures. This substantiates the reasoning with respect to Group II errors.

Since, as just shown, the resultant effect of Group I and Group II errors is opposite, it is obvious that at some lagging power factor the meter will be independent of changes in temperature. In the meter of Fig. 1, this lagging power factor is approximately 80 per cent as the curves meet here in a common point. This point will vary up and down the power-factor scale, depending on the relative magnitude of the resultant effects of Group I and II errors.

If, however, leading power factors are used in place of lagging power factors, the resultant effect of Group II errors will be reversed and, therefore, Group I and Group II errors will not oppose each other. As a result, there is no leading power factor at which the meter is independent of temperature.

This is illustrated by the curves of Fig. 2 where the broken lines are the corresponding leading power-factor curves to the solid or lagging power-factor curves.

It should be noticed that the leading power-factor curves, although similar in form, are opposite in direction to the lagging power-factor curves and therefore do not meet in a common point.

The effect of leading power factors, as far as single-phase meters are concerned, is of little importance, since single-phase meters are rarely subject to leading

power factors, but with two-element polyphase meters this is not necessarily true. In the first place, polyphase meters are more apt to be used where leading power factors exist, and in the second place, a polyphase meter at lagging load power factors above 86.67 per cent has one element operating on a leading power factor. The two elements would tend, therefore, to compensate each other as far as temperature errors are concerned.

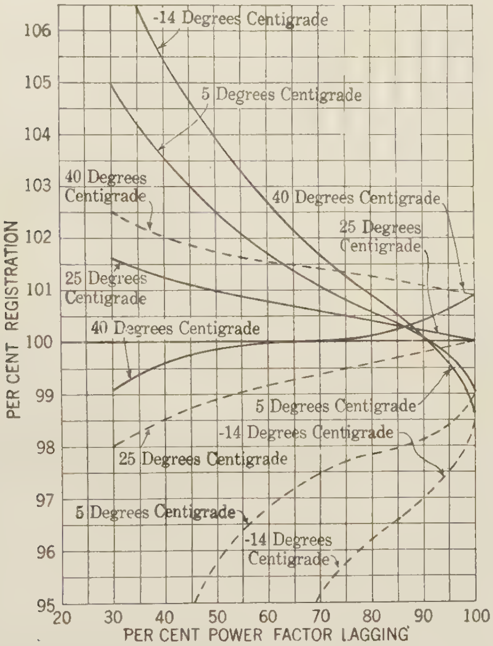

Fig. 2—Effect Upon the Typical Performance Curves of Leading Power Factors

This probably accounts for the fact that polyphase meters in general have less over-all temperature error at low power factors than do single-phase meters of the same make.[4]

Effect of Changes in the Constants and Materials of the Meter

Any change in the constants of the meter circuits, in the materials of which they are made, or in the design of the meter will change the relative magnitude of the several errors and thereby change the typical performance curves. The effect of some of these changes will now be illustrated.

Fig. 3 shows the effect of a brass phasing plate in the meter of Fig. 1. Since brass has a lower temperature coefficient than copper, its resistance will change less with a given change in temperature than the copper plate, and, therefore, the error due to this change will be less pronounced. Comparing Fig. 3 with Fig. 1, it is seen that the spread of the curves in Fig. 3 is less and the neutralizing or crossing point has been lowered. This means that the resultant effect of Group II errors has been reduced so that they do not overcome the resultant effect of Group I errors as quickly as in Fig. 1. Furthermore, the spread of the curves at the lower power factors has been greatly reduced. This indicates that error No. 10 is the predominant one of the Group II errors. This figure also illustrates that it is possible by proper calibration to get virtually perfect performance at some one temperature, 20 deg. cent. in this case.

The substitution of a lag plate which has nearly zero temperature coefficient has been suggested, but, unfortunately, all the metals which have low temperature coefficients also have high specific resistance. Even with brass, it is necessary to use a plate nearly four times as thick as the copper plate it replaces, in order to obtain the proper lagging. The design of the average present-day meter has a relatively small space available for the lagging device with the result that the limit to which this idea can be carried without materially changing the dimensions of the meter, is quickly reached.

In order to determine the effect of error No. 8, two otherwise similar meters were made up, one with its

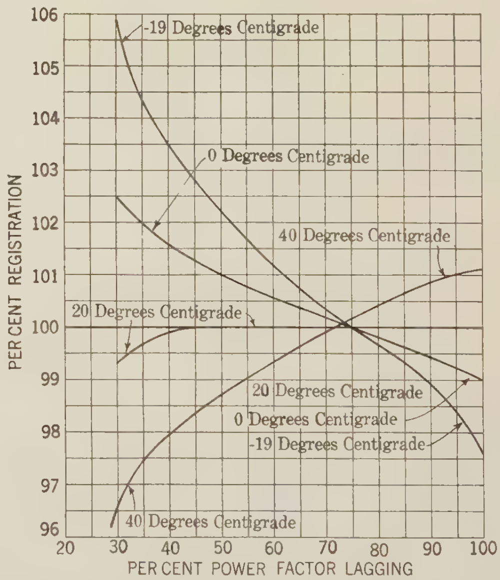

Fig. 3—Effect Upon the Typical Performance Curves of Substituting a Brass Phasing Plate for the Customary Copper Plate

potential coil resistance increase above normal and the other with its potential coil resistance decreased below normal.

The first of these meters was obtained by winding the potential coil with the same number of turns of No. 33 wire instead of the customary No. 30. Neglecting a small change in the mean length of turn, the resistance of these coils would be approximately twice the normal resistance.

Since increased potential losses mean a decrease in the angle between the applied voltage and the flux

4. See the author's paper, "Watthour Meter Accuracy as Affected by Temperature Changes," *Experiment Station Bulletin* No. 22, Purdue University.

set up thereby (see Fig. 12), it follows that greater lagging must be applied to this meter. It was found that to obtain the proper lagging, a larger or thicker lag plate was required than that normally used.

Turning now to Table I, it is evident that both errors

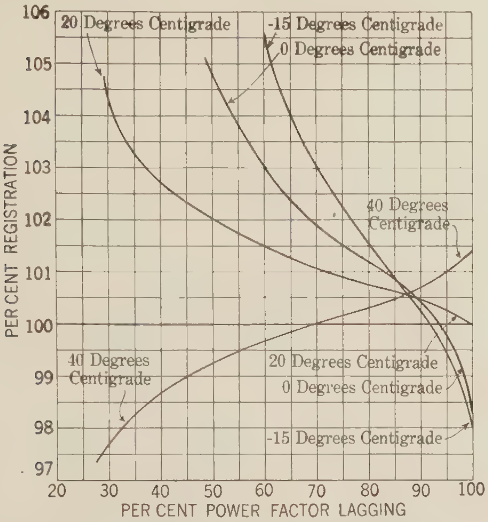

Fig. 4—Effect Upon the Typical Performance Curves of Increasing the Resistance of the Potential Winding Above Normal

No. 8 and 10 will be affected and moreover in the same direction. The result is an increase in the resultant effect of Group II errors. This means that Group II errors are now better able to overpower Group I errors,

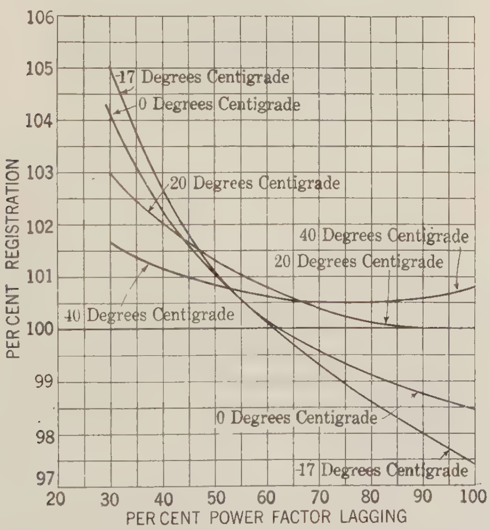

Fig. 5—Effect Upon the Typical Performance Curves of Decreasing the Resistance of the Potential Winding Below Normal

thereby raising the crossing or neutral point on the power factor scale.

The result of the test is plotted in Fig. 4. Comparing these curves with those of Fig. 1, it is seen, as had been predicted, that the crossing point has moved from approximately 80 per cent power factor to nearly 90 per cent. This is a desirable change as far as high power-factor operation is concerned, but it should be noticed that at the lower power factors, the spread of the curves has been greatly increased.

Although this meter is compensated to some extent at high power factors, it is accomplished at the expense of accuracy at low power factors, and, furthermore, any compensation which depends upon an increase in the losses is fundamentallly wrong.

The second meter referred to above was obtained by winding the potential coils with two strands of No. 30 wire instead of the customary single strand. As before, neglecting the change in the mean length of turn, the resistance of these coils would be approximately half the normal resistance.

Also as before, a change in the lag plate is necessary, but in this case in the opposite direction. A No. 16 brass phasing plate was substituted for the customary

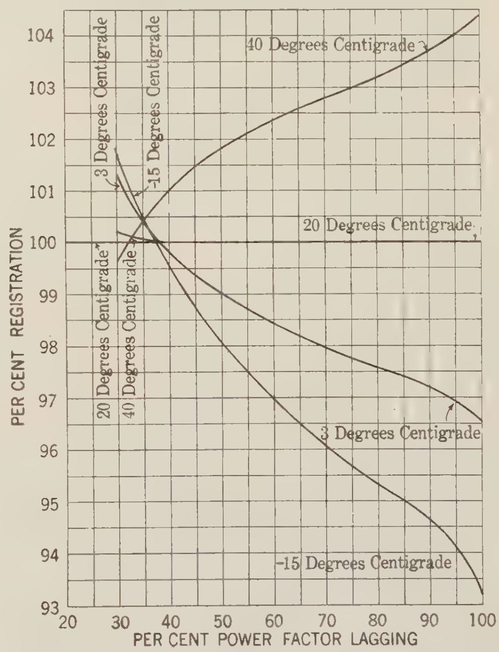

Fig. 6—Effect Upon the Typical Performance Curves of Lagging Both the Potential and Current Fluxes

copper plate. The result of these changes is just the opposite to that obtained with an increase of resistance.

The effect upon the performance curves is shown in Fig. 5. Comparing these curves to those of Fig. 1, it is evident that the crossing occurs at lower power factors and with less variation at very low power factors.

This is obviously a step in the right direction as far as Group II errors are concerned, but it is equally obvious that it is not a complete solution as it would be impossible to have zero resistance in the potential circuit, so doing away with the lag plate entirely.

In Fig. 5, the curves show the meter running fast at all temperatures on low power factors. This is due to over lagging of the meter when it was adjusted and calibrated. Had it been properly lagged at the customary 50 per cent power factor, the curves as a whole would have been more nearly coincident with the 100

per cent registration line, but the spread of the curves at either end would not have been changed appreciably.

As previously mentioned, changes in design will also affect the typical performance curves. As an example, consider the simultaneous lagging of both the potential and current fluxes. This is done by over-lagging the potential flux and then lagging the current flux sufficiently to produce the required 90 deg. relation between them at unity power factor.

As the temperature increases in a meter so modified, it will tend to lessen the lagging of both the potential and current fluxes. By proper proportioning of these

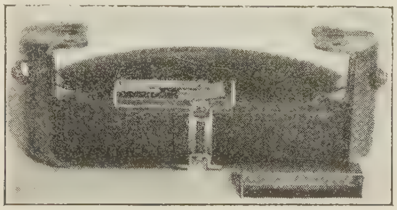

Fig. 7—The Compensating Device Used for Group I Errors—Cover Removed

two lag plates, it might be possible to shift these two fluxes by approximately the same amount for a given change in temperature so that the angle between them would remain at 90 deg.

Fig. 6 shows the result of an attempt to apply this principle. Comparing these curves with those of Fig. 1, a slight improvement is found in the slope of the curves.

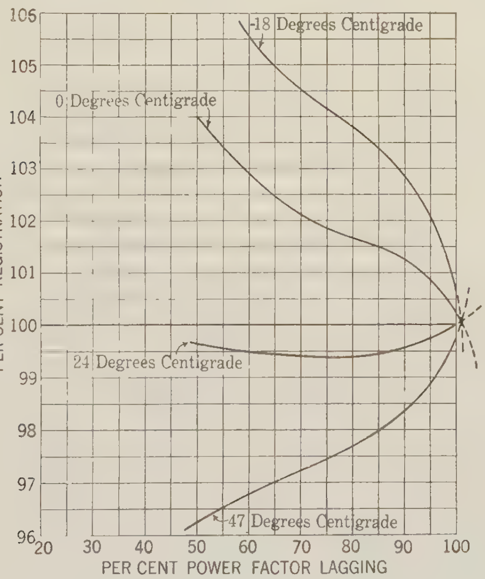

Fig. 8—Effect Upon the Typical Performance Curves of the Compensating Device For Group I Errors

This means that Group II errors have been partially compensated for. The effect, however, is not very pronounced.

Type of Compensating Devices Found to be Most Effective

The compensating device found to be most effective for Group I errors in the meters investigated consisted of a flux diverter for the permanent magnet. This diverter was mounted across the gap of the magnet on a bimetal strip, so that it moved out or in as the temperature went up or down. See Fig. 7.

The law which this diverter obeys depends on the relative magnitude of the magnetic pull upon it and the spring and thermal action of the bimetal strip. These, in turn, depend on the position, size, and shape of the iron diverter and bimetal strip.

The effect of this device on the meter of Fig. 1 is shown in Fig. 8. This figure shows that by this means it is possible to over-compensate for Group I errors, as the crossing point has moved beyond the 100 per cent power-factor point. By moving the diverter away from the gap, the crossing point may be made to occur at 100 per cent power factor exactly. It should be noticed that the removal of Group I errors leaves Group II errors unrestrained, as shown by the excessive spread of the curves at low power factors.

From what has just been said, it is evident that two independent compensating devices are needed, one for

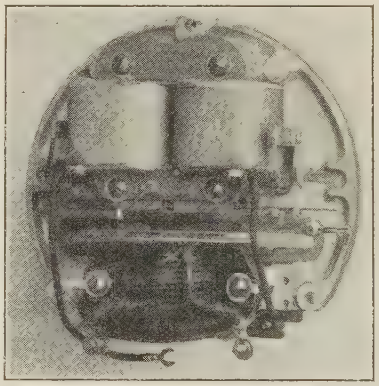

Fig. 9—The Compensating Device Used for Group II Errors

Group I errors and another for Group II errors, to completely compensate a meter for changes temperature.

The compensating method found most effective for Group II errors consisted in mounting the phasing plate on bimetal strips in such a way as to cause it to move up and down with a rise and fall of temperature. See Fig. 9.

The effect of this device alone on the meter of Fig. 1 is shown in Fig. 10.

The effect of both of these devices combined in the same meter resulted in the performance shown in Fig. 11, which, when compared to Fig. 1, shows a marked improvement.

The solid curves are the average curves of ten separate tests made on this meter at frequent intervals over a period of four weeks. Between tests the meter received average handling and transportation and was not found to be appreciably affected by this treatment.

This would indicate that although movable com-

pensating devices are used, they are rigid enough to withstand ordinary handling.

The dash lines represent the maximum deviation from 100 per cent registration of any one of six compensated meters, each tested three times between -18 deg. cent. and 40 deg. cent. and 100 per cent power factor and 30 per cent power factor.

In other words, the solid curves of Fig. 11 illustrate the best performance obtained thus far in any one meter as a whole by careful adjustment. The dash lines on the other hand represent the poorest performance of any of six different meters taken severally.

This would indicate that compensated meters of this type might be produced and calibrated by the customary methods of production and testing and have none of its temperature power factor registration curves outside the range bounded by the dash lines of Fig. 11, and will on the average be better.

Conclusions

To completely compensate a meter for changes in temperature two independent compensating devices are needed, one to compensate the meter at unity power factor or Group I errors and another to compensate the meter at any power factor other than unity, or Group II errors.

The compensating device found most effective for Group I errors is a permanent magnetic flux diverter mounted on a bimetal strip across the gap of the magnet

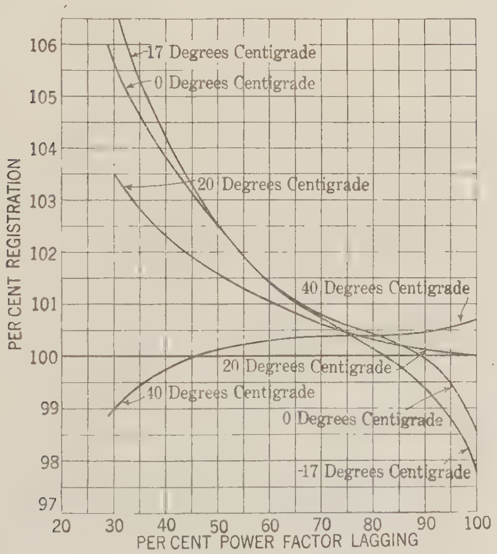

Fig. 10—Effect Upon the Typical Performance Curves of the Compensating Device for Group II Errors

in such a way that it moves in or out with decrease or increase in temperature.

The compensating method found most effective for Group II errors consisted in mounting the phasing plate on bimetal strips in such a way that it moves up or down with increase and decrease in temperature.

A meter equipped with these devices and carefully adjusted will not vary over one-half of one per cent between 100 per cent and 50 per cent power factor over a temperature range of 40 deg. cent. to -18 deg. cent. From 50 per cent power factor to 30 per cent power factor, a change of about one per cent in registration takes place. Six meters equipped with these devices did not vary more than $\pm$ ¼ per cent at unity power factor and did not exceed $\pm$ 1 per cent at thirty per cent power factor over the above mentioned range of temperature.

It should be noticed that even this change is relatively

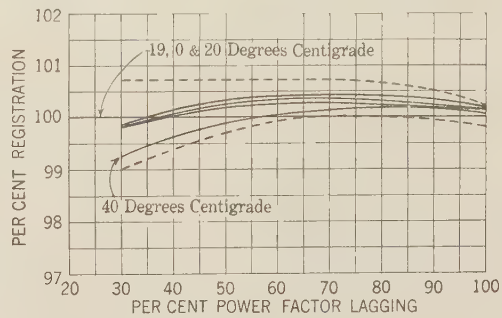

Fig. 11—Effect Upon the Typical Performance Curves of Both the Devices Properly Adjusted

small when compared to the variation in an uncompensated meter.

Ordinary handling and transportation of meters was not found to have any effect upon the compensating devices.

Appendix I

Vector Diagram of the Watthour Meter

In order to discuss the sources of temperature errors intelligently, it is necessary to have in mind the relations that exist between the many fluxes, currents and voltages that are present in a watthour meter.

Fig. 13 shows the fluxes that are present in a watthour meter whose magnetic circuits are as shown, and with but minor modifications, will suffice for most present-day meters.

Fig. 12 shows the relative phase relations of these various fluxes, currents and voltages.

It must be kept in mind during the discussion of these figures that they are purely theoretical, that many of the quantities shown are, from a practical point of view, negligible, and that therefore only an approximate attempt was made to draw these figures to scale.

Considering, first, the potential circuit with the lag plate removed, V is the applied voltage which causes the no-load current I_0 to flow. This current has both a core loss and magnetizing component not shown in the figure.

The current I_0 produces the flux Φ and what leakage flux exists, Φ_L. The flux Φ sets up a back e. m. f. at right angles to it, which requires the primary component E to balance it. By adding E to the voltage

drop of the potential winding, which consists of $I_0 R_1$ in phase with I_0 and $I_0 X_1$, at right angles to I_0, the diagram closes on V.

The flux Φ divides at a (see Fig. 13), into two fluxes Φ_1 and Φ_2, of which Φ_1 is much the larger, due to the low reluctance of its path as compared to that of Φ_2. However, vectorially $\Phi_1 + \Phi_2 = \Phi$ as shown in Fig. 12.

If, now, the lag plate is placed in circuit as shown, Φ_2

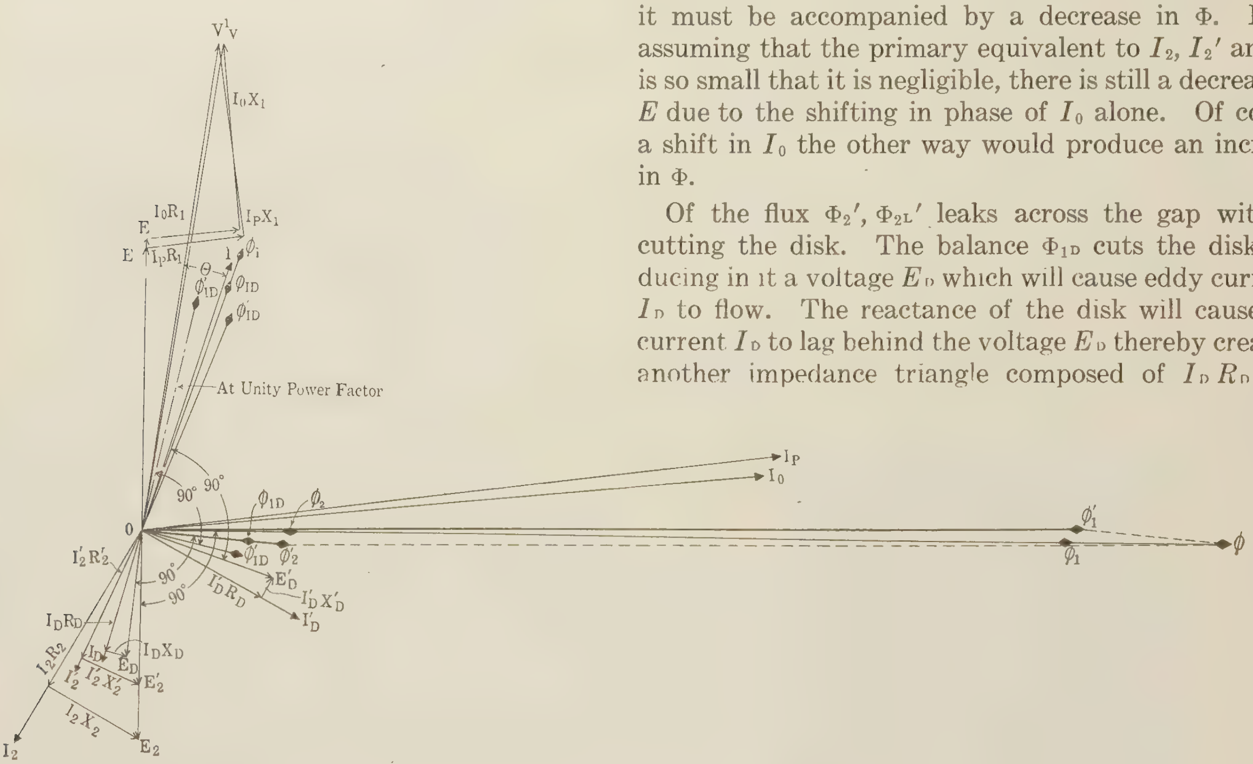

FIG. 12—A THEORETICAL VECTOR DIAGRAM OF AN INDUCTION TYPE WATTHOUR METER

will induce in it a voltage E_2. The voltage E_2 causes a current I_2 to flow. Since the lag plate is only one short-circuited turn, the voltage E_2 is used up in the $I_2 R_2$ and $I_2 X_2$ voltage drops of the lag plate.

In like manner, the flux Φ_2 will induce in the light-load plate a voltage E_2'. This voltage will cause a current I_2' to flow. Since the light-load plate is also only one short-circuited turn, the voltage E_2' will be used up in the $I_2' R_2'$ and the $I_2' X_2'$ voltage drops of the light-load plate.

The currents I_2 and I_2' will both produce a m. m. f. which when combined with the m. m. f. producing the flux Φ_2 will produce some other flux Φ_2'. Some of this change is transmitted to Φ_1, which now becomes Φ_1'. Assuming for the moment that the sum of these new fluxes, Φ_1 and Φ_2', is again vectorially equal to Φ, the relation will be shown by the heavy lines in Fig. 11. As will be pointed out later, this assumption is not quite true, but is a very close approximation[5].

5. "Theory and Operation of Split-Phase Magnet," *Electrical World*, Vol. 68, No. 21, Nov. 18, 1916.

The currents I_2, I_2' and I_D must have a primary equivalent to balance them. This primary load current will change the position and magnitude of I_0 to I_p. This change will also change $I_0 R_1$ to $I_p R_1$, and $I_0 X_1$ to $I_p X_1$, both in magnitude and position. Assuming for the sake of simplicity that E is fixed in position and V fixed in magnitude, these changes will have the effect of moving V to V^1 and decreasing E to E^1. This decrease in E is the fallacy in the above assumption for it must be accompanied by a decrease in Φ. Even assuming that the primary equivalent to I_2, I_2' and I_D is so small that it is negligible, there is still a decrease in E due to the shifting in phase of I_0 alone. Of course a shift in I_0 the other way would produce an increase in Φ.

Of the flux Φ_2', Φ_{2L}' leaks across the gap without cutting the disk. The balance Φ_{1D} cuts the disk, inducing in it a voltage E_D which will cause eddy currents I_D to flow. The reactance of the disk will cause the current I_D to lag behind the voltage E_D thereby creating another impedance triangle composed of $I_D R_D$ and

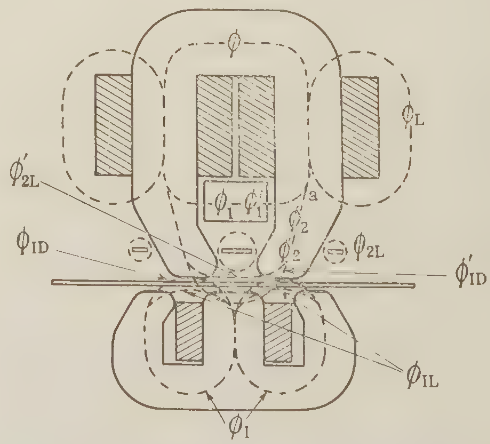

FIG. 13—FLUX DISTRIBUTION IN AN INDUCTION TYPE WATTHOUR METER

$I_D X_D$ closing on E_D. The eddy currents I_D produce a flux Φ_{1D} which reacts with the flux Φ_{2D} to produce a flux Φ_{1D}'. In other words, the disk reacts upon the potential circuit in much the same way as the lag plate and

light-load plate did. In effect it is a third secondary.

The line current I in the series coil which in general will lag behind the applied voltage V^1 by some angle θ will produce a flux Φ_I which will not be exactly in phase with I but will lag behind slightly. Part of this flux will leak across the gap. The balance Φ_{ID} will cut the disk, inducing in it an e. m. f. E_D' which sets up eddy currents I_D'. These eddy currents act in a similar way to the eddy currents I_D to produce the impedance triangle consisting of $I_D' R_D$, $I_D' X_D$ and E_D'. The flux set up by these eddy currents will react with the flux Φ_{ID} to produce the flux Φ_{ID}'. At unity power factor when I is in phase with V^1, Φ_{ID}' will take up some position as shown by the dotted line.

The process of lagging a meter places a 90-deg. relation between the flux Φ_{ID}' in its unity power factor position and the flux Φ_{1_D}' by varying the magnitude of I_2.

By adding to the meter the permanent magnet circuit whose function it is to produce a drag upon the disk proportional to its speed, the circuits of the watthour meter are complete.

Appendix II

Sources of Temperature Errors

It is evident that any changes in the magnitude of the driving or dragging fluxes or in the fundamental 90-deg. relation referred to in Appendix I, will change the registration of the meter. This fact suggests a convenient grouping of the sources of temperature errors in watthour meters, Group I to contain those factors which produce a change in the magnitude of either the driving or dragging fluxes or both and Group II to contain those factors which produce a change in the phase position of the driving fluxes.

Furthermore, the effect of Group I and Group II factors will be different on an increase in ambient temperature from that on a decrease in ambient temperature and the effect of Group II factors will be different on lagging power factors from that on leading power factors. There are, therefore, four combinations possible, as follows:

Combination I—Increase in ambient temperature with lagging power factors,

Combination II—Increase in ambient temperature with leading power factors,

Combination III—Decrease in ambient temperature with lagging power factors,

Combination IV—Decrease in ambient temperature with leading power factors.

For the purpose of the following discussion, consider Combination I. Also consider each effect as existing independently of every other effect, although, of course, they will exist simultaneously in the meter.

It is well understood that an increase of temperature will produce a decrease in the permeability of magnet steel, with a consequent increase in reluctance and decrease in flux. In the case of the permanent magnet this will speed up the meter as it is the dragging flux that is reduced, but in the case of the potential and series elements it will decrease the speed of the meter, as here it is the driving flux that is decreased.

Since most permanent magnets are bent, expansion caused by an increase in temperature will tend to widen temporarily the gap between the poles. The effect of this upon the speed of the meter will depend upon the design of the drag magnet circuit. In general, it can be said that meters using the flux in the gap between the poles for their dragging effect will increase in speed while meters which use a shunted portion of this flux to produce the dragging will slow down.

The effect of an increase in temperature upon the exciting current I_0, Fig. 12, due to changes in the iron losses was determined by experimenting with a transformer and found to be two-fold. There is first a shift downward in phase position and second an increase in magnitude in such a way as to decrease the core loss component and increase the magnetizing component of I_0. As previously pointed out, the effect of the first of these is to increase the length of the vector E^1 through a shift in the impedance triangle and the second to decrease the length of this vector. These changes must be accompanied by corresponding changes in the magnitude of Φ and, therefore, the speed of the meter.

An increase in temperature will increase the resistance of the lag and light-load plates, thereby decreasing the eddy currents set up in it. This in turn will decrease choking effect of these plates upon the flux producing these eddy currents, allowing more of it to pass to the disk. This will speed up the meter.

An increase in the resistance of the potential winding will cause the exciting current to shift more nearly in phase with the applied voltage. This shift as before decreases E^1 through a shift in the voltage triangle of the potential coil. This must be accompanied by a decrease in Φ and, therefore, the speed of the meter.

In Group II, there is first an increase in the resistance of the potential winding. This will cause the speed of the meter to decrease since it causes a decrease in the 90-deg. relation between the driving fluxes.

The effect of the change both in phase position and in magnitude of the exciting current will cause the meter to decrease in speed since both tend to decrease the 90-deg. relation between the driving fluxes.

The increase in resistance of the lag and light-load plates causes a decrease in the lagging effect and a consequent decrease in the speed of the meter.

An increase in the resistance of the disk will cause a decrease in the eddy currents I_D and I_D' (Fig. 12) set up in the disk and a consequent decrease in its speed. This change, however, is balanced by a corresponding decrease in the dragging effect of permanent magnet which speeds up the disk by exactly the same amount.

Hence there is no Group I error due to the change in resistance of the disk.

An increase in the resistance of the disk will also cause

I_D and I_D' to shift towards E_D and E_D', respectively. This will shift Φ_{1D}' and Φ_{ID}' in the same sense, thus tending to maintain the 90-deg. relation between them.

These two fluxes do not shift by the same amount, however. Since I_D' is the only current producing a m. m. f. affecting the phase position of Φ_{ID}', its effect is more pronounced on Φ_{ID}' than is the m. m. f. of I_D upon Φ_{1D}'. The result is a decrease of the 90-deg. relation between these two fluxes and a consequent decrease in the speed of the meter.

This effect can be demonstrated by using disks of different resistances in the same meter. In the particular experiment tried, a maximum shift in the position of the disk in the gap accounted for only 50 per cent of the change in registration due to a change in the resistance of the disk. The balance must be due to a greater shift in Φ_{ID}' than in Φ_{1D}', thereby decreasing the 90-deg. relation between them and consequently the speed of the meter. This is a Group II error.

Table I gives a summary of the above discussion using Combination I. The first seven errors comprising Group I are independent of the power factor, operate at all power factors, and are constant at any given temperature. The remaining errors comprising Group II are a minimum at unity power factor, but increase with a decrease in the power factor.

The effect of Combination II on Table I will be to reverse the effect of Group II errors, of Combination III to reverse the effect of both Group I and Group II errors, and of Combination IV to reverse the effect of Group I errors.

Since the analysis of the sources of error in this investigation is only incidental to the development of methods of compensation, not enough work was done to claim that the above discussion and the summary in Table I cover all of the possible sources of error due to temperature. For example, the effect of temperature on the light-load plate has not been considered, except as it functions as a part of the artificial lagging of the meter.

Oil Breakdown at Large Spacings

BY DOUGLAS F. MINER[1]

Associate, A. I. E. E.

Synopsis.*—Much work has been done on the breakdown of insulating oil at small spacings between electrodes. Information for electrode separations of several inches is not as complete. It has been found that sources of ionization external to the gap influence the gap breakdown, so that the design of electrode supports and parts is of great importance.*

Data on several sizes of spherically terminated rods or cylinders are presented. Short-time breakdown tests are shown to be quite erratic and a form of long-time test schedule was developed which gives more consistent results. The final test used is called a ten-minute-hold and yields values for a given condition representing the maximum voltage that can be held consistently. This is of special interest in design.

The empirical curves of oil breakdown are analyzed by mathematical methods. A general equation for breakdown voltage in terms of electrode diameter and separation is developed which agrees quite well with the experimental data.

Evidence is presented to show that water in globular form suspended in oil may increase the breakdown potential considerably with spherical electrodes if the separation is several times the diameter.

* * * * *

In common with other dielectrics, whether gaseous, liquid, or solid, transformer and switch oils exhibit a non-linear relation between breakdown voltage and spacing of electrodes in the dielectric. The breakdown value of the standard test cup spacing gives no clue as to the breakdown at large spacings. In bulk, oil has a relatively low dielectric strength due to the rapid increase in ionization by collision. Ionization at the electrodes leads to local breakdown and consequent total rupture. Thus the shape of the electrodes and supports is of prime importance. It is essential that the breakdown between the electrodes chosen is not influenced by corona in the neighborhood, originating in some part of the support with a smaller radius of curvature than the electrode itself. In order to yield useful data on large oil spacings, work has been carried on under carefully controlled conditions.

A number of excellent studies of oil breakdown at small spacings (below two to four in.) have been made[2] and reliable data are available. At larger distances, however, the data are not as complete. The results to be discussed help to fill out this region and will serve as guides to design where such spacings are necessary.

When the characteristics of materials are investigated, it is always a question whether the material tested should be in ideal condition—a perfect sample, or an average. This will depend on whether the object is to arrive at the maximum quality or at that which can be relied upon for a general run. In the case of insulating oil, extremely high dielectric strength can be obtained with carefully filtered and vacuum dried samples (50 kv. r. m. s. for standard 0.1-in. gap between one-in. diameter flat electrodes).

This quality is exceptional, however, and cannot be commercially maintained. Both the designer and the operator of apparatus have to rely on what more nearly

1. Section Engineer, Experimental Section, Westinghouse Elec. and Mfg. Co., East Pittsburgh, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

2. Bibliography, 1, 5, 6, 7.

approaches the allowable minimum instead of the maximum quality. For example, good oil of commercial grade may test 30 to 35 kv., r. m. s. for standard test, but in apparatus the oil may be allowed to deteriorate to the point where it tests 22 kv., r. m. s. before it is considered unsatisfactory. The weakest point in insulation or the poorest condition the oil may be in, under normal good practise, may determine the factor

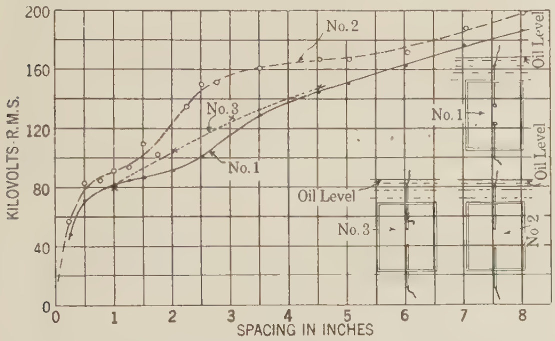

Fig. 1—Oil Breakdown—Effect of Ionization—5/8-In. Diameter Spheres. (Each Point is Average of Three or More Tests)

of safety of the insulation. These tests, therefore, were made at room temperature using transformer oil of good commercial quality testing 30 to 35 kv. for 0.1 in. in the standard test cup.

I—Effect of Ionization on Oil Breakdown

Before considering the test data on large spacings, it will be necessary to present evidence to show why it is important to eliminate ionization other than that of the electrode itself. A set-up was made using 5/8-in. diameter spherical electrodes, placed vertically in an insulating frame under oil. Comparison of breakdown was made with

a. 5/8-in. sphere with 1/10-in. diameter shanks,
b. 5/8-in. spherical ended rods,
c. 5/8-in. spherical ended rods with sharp wire attached.

Test Conditions. The oil was in very good condition, having been obtained fresh, and testing better than 35 kv. for 0.1-in. gap. The test tank was 3½ ft. in diameter and 5 ft. deep. Voltage supply was a 300-kv., 100-kv-a., 60-cycle testing transformer with drum controller giving 500-volt steps on the high side. The tests were what is known as three-minute-hold tests in which the voltage is raised continuously to about 70 per cent of breakdown and then increased at the end of three-min. intervals by five per cent increments. The value used is the last voltage successfully held. The frame for holding the electrodes was made of bakelite paper micarta strips ½ in. thick and four in. wide with a length of 24 in. and width of 20 in. The arrangement is shown in Fig. 1. The sharp wire was a piece of No. 18 B & S copper wire wound around the upper electrode and bent down, the tip being two in. back of the end of the electrode and two in. out to the side.

The three curves of Fig. 1 show clearly the relative breakdown. At spacings up to 1½ in., the rods show slightly higher breakdown (15 per cent) but with separations from 2 in. to 5 in., a pronounced increase over the spheres is apparent. The rod curve can be brought down nearly to the sphere curve by the addition of the auxiliary source of ionization shown. This test, being typical of results obtained, shows the effect of the electrode support shape. For this reason the tests subsequently described were undertaken with electrodes of such a design that no metal part had a radius of curvature less than the end of the electrode. Spherical-ended cylinders or rods satisfy this requirement.

II—Oil Breakdown at Large Spacings

In undertaking to obtain data under the limitations imposed, a considerable amount of study and work was put on the design and construction of testing apparatus. A description of this will be given to show difficulties encountered and methods used. The two chief difficulties were in bringing the high potential lead into the oil and in building a test frame that would not fail mechanically or electrically.

A small-sized wire (No. 18) was first used for a lead-in, entering the oil surface in the center of a 20-ft. diameter tank and connecting several feet below the surface to the electrodes under test. This form of lead showed great disturbance, especially at the oil surface, and flashover occurred over a radial distance of

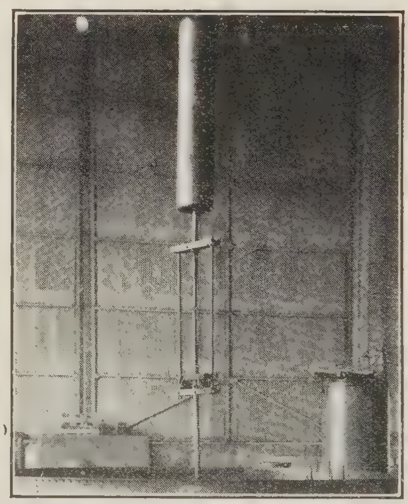

Fig. 2—Arrangement of Oil Testing Electrodes

10 ft. at 350 kv. This was due to the excess gradient adjacent to the oil surface which accompanies the distortion of flux due to difference in dielectric constants of air and oil. Excessive corona was evident above the oil surface. A 3⅛-in. diameter brass pipe was later used, being suspended from a string of suspension insulators. This brought about very little improvement, allowing tests up to 400 kv. only, before flashover occurred. This means that the average gradient over the 10-ft. distance is only about three kv. per in.

whereas needle points 10 ft. apart flash at 1200 kv. or 10 kv. per in.

The final form of lead adopted is shown in Figs. 2 and 3. It consists of a micarta tube 8 ft. long (spliced) and 21 in. in diameter, covered with thin sheet metal smoothly applied and carefully soldered at the joints. The lower end was fitted with a toroidal piece of wood sprayed with copper. The torus (4-in. section) was cut away to fit flush with the outside of the cylinder. This device was suspended from insulators and electrically connected to a 3⅛-in. diameter brass tube running through the center. The testing rig was hung on this tube. Test voltages up to 700 kv. or more are successfully brought beneath the oil surface with this form of lead.

The first structure used to hold the rod electrodes was a crude affair built to determine the requirements of the problem. It consisted of a spruce board on which two porcelain pillars were mounted 31 in. apart and the rods

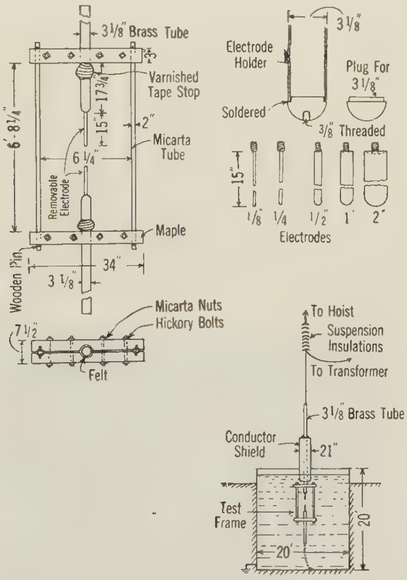

Fig. 3—Test Frame. Electrodes and Arrangement of Apparatus

clamped to these. This arrangement was tied to an 18-ft. wooden ladder and suspended horizontally in the 20-ft. tank. Ropes on the ladder aided in raising and lowering the outfit for adjustment.

The board soon failed by leakage and when the ground wire was arranged not to touch the board, the ladder and supporting rope finally showed leakage and burned badly. The porcelain pillars were also chipped and fused. From this it was shown that a highly insulating frame must be made with no metal parts to cause corona or parts of widely differing specific inductive capacity to cause stress concentration.

The second frame was built of micarta tubes and wooden end clamps arranged for a vertical gap. See Fig. 3.

Two micarta tubes 2-in. in diameter were used with split end pieces of maple clamped around the tubes with ¾-in. threaded wooden rods and micarta nuts. The upper electrode was a 3⅛-in. brass tube passing through the upper wooden pieces for an adjustable length. The frame was clamped to this tube so that the whole rig was hung from it. The lower electrode was a similar brass tube extending below the frame three ft. and ending in a chain which was dropped to the bottom of the tank for a ground connection. The inner ends of the brass tubes were closed with a hemispherical plug tapped to receive various-sized rods, so designed that no threads or parts were exposed with a radius of curvature smaller than the electrodes under test.

The conclusion drawn from these experiences is that for very high voltage tests under oil, wood, even the best seasoned hardwood commercially obtainable, is unsatisfactory as an insulator. It is suitable for a nonmetallic spacer or mechanical support but the insulation must be obtained from porcelain, micarta, fuller board, or similar high class dielectrics.

Two transformers were used in these tests, one 500 kv., 500 kv-a., 60 cycle, 5000 volts primary; and the other 1000 kv., 1000 kv-a., 60 cycle, 5000 volts primary. Both of these are single-terminal, one end grounded units.

Voltage was measured by both crest voltmeter and ratio meter checked against sphere spark-gap values.

Test Methods and Results. Early tests demonstrated that with favorably controlled conditions (no neighboring ionization due to sharp corners, bolts, etc., and no adjacent field-distorting bodies) instantaneous breakdown values were obtained higher than those given in any existing data. This is of great value in determining the maximum strength of oil. Wide variations in test results were found, however. Later work involved the introduction of time tests and the tendency has been towards data on maximum holding voltages for longer times, one min., three min., five min. and finally 10 min. More consistent data, although much lower than instantaneous breakdown, are hereby obtained. From a design standpoint, these are the values usable in calculating oil insulation—the long-time holding voltages and not the occasional extra high voltages. The curves shown in this report are based on over 1850 observations or applications of potential, a large number being for 10 min.

The discouraging diversity of points shown in the instantaneous breakdown curves led to a study of test conditions, voltage measurement, etc., but reasonble control of these factors did not yield satisfactory results.

Curves of average values do not tell the whole story, especially with instantaneous breakdowns. We consequently have shown in some cases a number of representative points. The relation of average to maximum and minimum can be seen and the dispersion demonstrated.

Instantaneous Breakdown. It has been noted by several observers that oil breakdown for short-time application of voltage is quite variable, even when

greatest care in controlling conditions is exercised. This deviation from an average value is far greater than with air[3]. This variation was shown by Hayden and Eddy to be a characteristic of oil apparently due to its chemical complexity. Other dielectrics, such as benzol, were not as erratic. Filtering, vacuum treatment, high temperature, etc., were found to be ineffective in changing this behavior.

Fig. 4, a typical curve, shows the individual breakdown points for one-in. diameter electrodes against spacing.

Voltage was raised continuously by induction regulator to breakdown in less than one min. It is at once

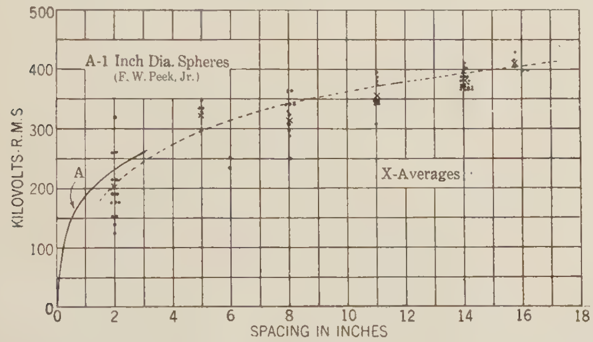

FIG. 4—INSTANTANEOUS BREAKDOWN VOLTAGES OF ONE-INCH DIAMETER RODS

apparent that the widest deviation occurs at small spacings (two in.). For example, with the one-in. electrodes, two-in. breakdown varies between 125 kv. and 320 kv., over 100 per cent.

The following table shows typical results obtained, being data for the two-in. diameter curve.

Spacing in Inches	Instantaneous Breakdown in Kv.
2	310, 285, 285, 285, 328, 260, 315, 190, 265, 315, 140, 180, 165, 175
4	320, 235, 310, 390, 275, 210
5	375, 340, 295, 285, 410, 365, 340, 295, 345, 325
8	360, 345, 390, 350, 345, 410, 450, 340, 470
11	425, 450, 390, 460, 340, 480, 475, 480, 480
12	380, 380, 380
14	410, 425, 370, 350, 450, 360, 460, 470, 450

This dispersion decreases in all cases with increased spacing, giving credance to the idea that with small gaps, there is an erratic lining-up of conducting particles or ionized oil. With longer distances, these variations are ironed out into an average state of conductivity. Thus the effect of poor oil will be more evident at small separation. The instantaneous data are presented to show that even an average of a large number of points cannot mean much when individual tests may depart 50 per cent in either direction from the average curve. After spending months trying to improve the consistency by a study of test conditions and voltage measurement, we were thoroughly convinced that the proper form of test of oil spaces is a time test in which the minimum consistent holding value of potential will be found.

3. Bibliography, 4.

One-Minute and Three-Minute Tests. This test is defined as the maximum voltage that can be held for one min. without breakdown. Two methods were tried in determining these data, the step method and the curve method (see Fig. 5). After several series of tests made with these methods, the improvement in the matter of consistency hoped for, was not

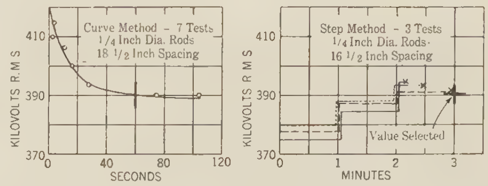

FIG. 5—BREAKDOWN VOLTAGES, ONE-MINUTE HOLD METHODS (CURVE AND STEP)

obtained. The step method was found to be preferable. The time was then extended to three min. Much better agreement between data taken at three different times some months apart is noted. The variation is still excessive for a relatively small number of tests. Fig. 6 shows a typical curve.

Ten-Minute-Hold Tests. Instead of increasing the number of tests, it was felt that a better method was to increase the time to 10 min., tending to eliminate the occasional freak values. This followed successful use of the method on transformer insulation tests. The method is very slow and tedious but seems to yield

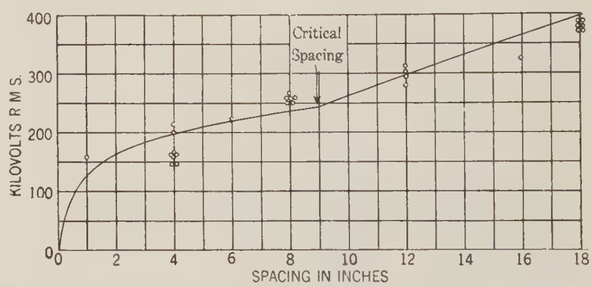

FIG. 6—BREAKDOWN VOLTAGES—THREE-MINUTE HOLD—ONE-HALF-INCH DIAMETER RODS

dependable results. A certain voltage is chosen below expected failure. This is applied for 10 min. and then taken off for five min. (to eliminate ionization), and is repeated five times. If no failure occurs, the voltage is raised a certain increment and the five 10-min. holds made. This proceeds until failure occurs during one or more of the five tests. Then the previous value is repeated five times and if checked (no failure), that value is selected as correct. Thus the least number of individual voltage applications necessary to determine one point is 15, requiring at least 225 minutes. Typical results of these tests are shown in Figs. 7 and 8, curves for points and one in. diameter electrodes. Fig. 9 gives a summary of 3-min. and 10-min. tests on logarithmic coordinates.

On some of the curves the data of various investigators have been shown for comparison. In Fig. 4, the curve for one-in. spheres given by F. W. Peek, Jr. appears slightly higher than the average curve of data obtained, but still well within the limits of individual points. Fig. 7 is an interesting comparison of

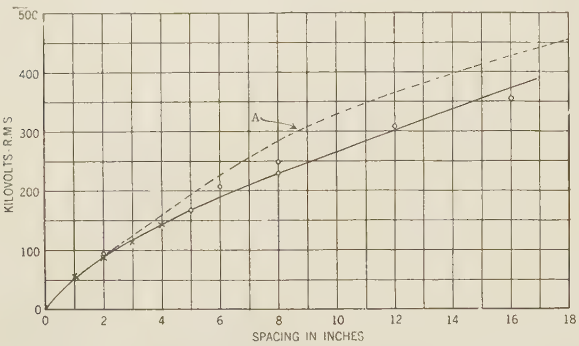

Fig. 7—Breakdown Voltages—Ten-Minute Hold Between Points

A—Needles, F. W. Peek, Jr.
o —Solid curve drawn from data of present investigation (Kv.-53 $S^{0.7}$)
x —Data from W. H. Tobey, A. I. E. E. 1910

data from three sources. The dash curve is taken from "Dielectric Phenomena," by F. W. Peek, Jr. and the solid curve is drawn from data of the present investigation (kv. = 53 $S^{0.7}$). The *X*'s are from data of W. H. Tobey[4] and coincide nicely with the present curve. It seems probable that Peek's curve represents instantaneous breakdown and is consequently higher. The ten-minute-hold values are much lower.

General Remarks on Test Results. From the results of the tests, the following may be inferred:

1. The instantaneous breakdown voltage for oils is

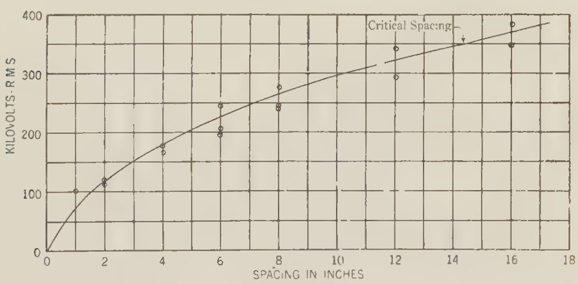

Fig. 8—Breakdown Voltages, Ten-Minute Hold, One-Inch Diameter Rods

not very definite, depending on too many factors that are sometimes not controllable.

2. The "time" tests show better consistency.

3. At short spacings, the breakdown voltage decreases with increased time of application of voltage. At large spacings, the differences between the sparking voltages for a long time of application and those for a short time of application are small and negligible.

4. The breakdown voltage increases with the diameter of the electodes at short spacing rather rapidly. At large spacings these values seem to be the same; that is, independent of the diameter.

4. Bibliography, 8.

Analysis of Test Data. The wide diversity of the test data rendered average readings for instantaneous tests unintelligible. Although results for the three-min. and 10-min. tests were more consistent, still there were some very pronounced deviations. In order to obtain conclusions that might prove of value in design, these data were analyzed so as to bring out some general relation that seemed to be representative of all the test data.

A. Three-Minute-Hold Values

Plotting results of the three-minute-hold tests on logarithmic paper, (Fig. 9) shows that all the curves seem to be tangent to a straight line at large spacings. From the manner in which the curves behave, it seems

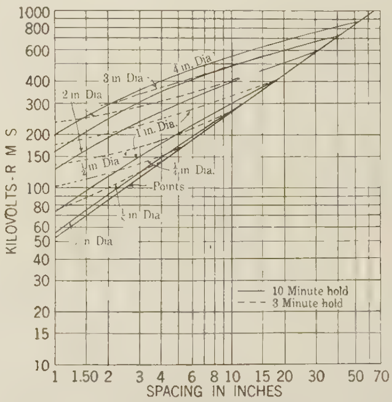

Fig. 9—Breakdown Voltages of Oil in Electrodes of Various Diameters on Three-Minute Hold

probable that the straight line denotes the sparking voltage for electrodes with diameter equal to zero, *i. e.*, for needle points. That all other curves are tangent to and emerge into this straight line may be explained by the following speculation as to the nature of oil breakdown.

It is assumed that there is a definite breakdown potential gradient for oil. When this gradient is reached at the surface of the electrode, the oil surrounding the rod is ionized, the effect being to increase the effective size of the electrode. Whether a complete breakdown as shown by a spark-over will follow this ionization or not depends on whether or not the increased size of the electrode causes the gradient to increase. Thus, if the spacing between the electrodes is large, the gradient decreases as ionization increases and in this case corona precedes a complete breakdown, so that if the applied voltage is not too high, only corona is observed. On the other hand, if the spacing is small, the gradient increases as ionization increases and a complete breakdown will follow as soon as the gradient at the surface of the electrode exceeds the breakdown value. It thus appears that for a given size of electrode there is a largest spacing—a critical spacing—at which no corona will occur before a complete breakdown.

Applying this to the case of two sharp points, it is seen that corona will always precede a complete break-

down. Thus, the sharp points are in effect two electrodes of varying diameter, their size being dependent upon the spacing and the applied voltage. For a given spacing the complete breakdown voltage is then the same as that for two electrodes having such a diameter that the given spacing is the critical one for such a size.

In the light of this speculation, we can readily explain why the curves for the electrodes with small diameters seem to intersect and finally emerge into the curve for sharp points. Thus the intersection of the ½-in. curve and the sharp point curve defines the critical spacing for ½-in. rod. At spacings greater than this, corona will occur first so that the breakdown voltage follows essentially the same curve given by the sharp points.

The points of tangency of the curves (on logarithmic scale) and the line denoting needle point might be thought of as those at which corona begins. These points as obtained from the curves do not agree with those that were obtained visually. The discrepancy might be due to the difficulties in making visual observations on the starting point of corona under oil or to the effect of surface irregularities. Above these points of tangency, the sparking voltage curves, on the basis of the above speculations, will follow a law different from that which holds below them. In constructing the sparking curves we should then expect a change in the direction of the curve at some point.

Mathematical Expression for Three-Minute-Hold Tests. As the plot on the logarithmic paper does not yield much information on the relations among the various curves, another plot was made on semi-logarithmic paper, since the general shape of the curves showed them to be of logarithmic form.

The straight line, *i. e.*, the probable curve for needle points on the logarithmic paper, becomes a curve on the semi-logarithmic paper. By trial it was found possible to represent the average test results approximately by a series of straight lines on the semi-logarithmic paper. The general form of the equations connecting the sparking voltage kv. and the spacing S is

$$\text{Kv.} = A \log S + B$$

or

$$\text{Kv.} = A \log \frac{S}{a}$$

where A and a are constants and Kv. = sparking voltage in kv., S = spacing in inches.

Moreover, when the various values of A and a were plotted on logarithmic paper against the respective values of the diameter of the rods, two parallel straight lines were obtained. Thus these two constants could be further expressed as functions of the diameter of the rods. These relations become

$$A = m\, d^n$$
$$a = c\, d^n$$

where m, c, and n are constants and d = diameter of rod in inches. Using these relations, it is then possible to express the sparking voltage in terms of the diameter and the spacing. Thus the general equation for the *three-minute-hold tests* is

$$\text{Kv.} = m\, d^n \log \frac{s}{c\, d^n}$$

With all the constants evaluated, this is

$$\text{Kv.} = 177 \sqrt{d} \log \frac{s}{0.16 \sqrt{d}}$$

It will be noted that the above equation does not become zero, for $S = o$. It will be noted, further, that the quantity whose logarithm is to be taken is large in all our cases. Thus if we add one to the number $S/0.16 \sqrt{d}$ and then take the logarithm, the values of the logarithm will not be increased greatly. In view of the fact that our data scatter more or less, such a modification will not change the results appreciably while the modified equations will give curves that do pass through the origin. Thus we have

$$\text{Kv.} = 177 \sqrt{d} \log \left(1 + \frac{S}{0.16 \sqrt{d}}\right)$$

for three-min. tests.

Curves calculated from this general equation have been plotted and found to be reasonably representative of the test data. For the smaller rods, these curves were calculated only up to the points where they intersect the probable needle-point curve. After that, since we assume the formation of corona, the curve is continued by the equation that represents the probable needle point, which, as already pointed out, is a straight line on logarithmic paper and hence is of the form Kv. = $D\, S^m$ in which D and m are constants. The numerical values substituted give the following as the equation:

$$\text{Kv.} = 53\, S^{0.7}$$

The following table gives the calculated values.

THREE-MINUTE-HOLD TESTS ON DIELECTRIC STRENGTH OF OIL

General Equation: Kv. $= 177 \sqrt{d} \log \left(1 + \frac{S}{0.16 \sqrt{d}}\right)$

d = Electrode Diam., (in.)	Breakdown Kv.
3 1/8	$312 \log \left(1 + \frac{S}{0.282}\right)$
2	$250 \log \left(1 + \frac{S}{0.226}\right)$
1	$177 \log \left(1 + \frac{S}{0.16}\right)$
1/2	$125 \log \left(1 + \frac{S}{0.113}\right)$
1/4	$88.5 \log \left(1 + \frac{S}{0.08}\right)$
1/8	$62.5 \log \left(1 + \frac{S}{0.057}\right)$
0	$53\, S^{7.0}$

B—Ten-Minute Tests

Applying the same general equation, *viz.*,

$$\text{Kv.} = A \log \left(1 + \frac{S}{a}\right),$$

it has been found that the following equation agrees with test results quite well.

$$\text{Kv.} = \left[380 + 120\left(1 - \frac{1}{d}\right)^4\right] \log \left(1 + \frac{d}{2} S\right)$$

in which Kv. = safe or holding voltage in kv.,

d = diameter of electrodes in inches,

s = spacing of electrodes in inches.

This is applied when ionization does not occur before breakdown. The same equation as before, kv. $= 53\, S^{0.7}$, applies when ionization precedes breakdown.

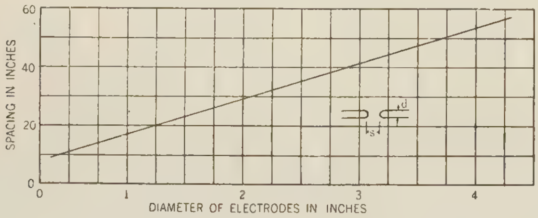

Fig. 10—Curve of Critical Spacing Ten-Minute Hold Tests

Spacing of which curves of rods intersect and emerge into needle-gap curve (graphical solution from calculated curve)

The intersection of these curves is called the critical spacing and might coincide with appearance of corona if accurate data were available. Fig. 10 was plotted showing the relation between calculated critical spacings and electrode diameter. The equation satisfied by diameters between ½ in. and 4 in. is $S = 5 + 12\, d$.

Breakdown curves for 3-in. and 4-in. diameter were calculated from the general equation. The equations for 10-minute-hold are as follows:

10-MINUTE-HOLD TESTS ON OIL

Electrode diam. (in.)	Breakdown Kv.
0	$53\, S^{7.0}$
½	$500 \log_{10}\left(1 + \frac{S}{4}\right)$
1	$380 \log_{10}\left(1 + \frac{S}{2}\right)$
2	$388 \log_{10}(1 + S)$
3	$404 \log_{10}\left(1 + \frac{3\,S}{2}\right)$
4	$418 \log_{10}(1 + 2\,S)$

Conclusions. The principal result of all this work is the development of more suitable test methods and the fundamental recognition of the inconsistency of short-time tests. Values obtained by long-time tests are much more reliable from a design point of view. On the basis of this information obtained with ideal or standard electrodes, future work of great value is possible, using electrodes of practical and special form.

TABLE I
AVERAGE KV. FOR INSTANTANEOUS BREAKDOWN, TEST VALUES

Spacing (In.)	Electrode Diam. (In.)				
	1/8	¼	½	1	2
2	225	..	290	205	245
4	285	..	315	275	325
6	335	315	345	325	370
8	370	335	365	355	410
12	405	370	400	390	450
16	435	425	430	410	490

TABLE II
AVERAGE BREAKDOWN KV. FOR ONE-MINUTE-HOLD, TEST VALUES

Spacing (In.)	Electrode Diam. (In.)	
	1/8	1/4
2	185	190
4	230	235
6	265	265
8	305	275
12	355	330
16	370	375

III—Effect of Water in Large Quantities

Oil Breakdown. Low breakdown of oil samples is frequently ascribed to moisture or foreign materials. It has long been known that very slight percentages of moisture in oil, when in a dissolved state, lower the test value at small spacings. For example, one part in 10,000 will reduce the dielectric strength of dry oil to about 30 per cent of its original value.[5]

Some evidence exists, however, showing that under certain conditions water may increase the dielectric strength of a mass of oil. In Report No. 25 of Electrochemical Laboratories, Tokyo, Japan, Dr. T. Hirobe presents a curve (Fig. 11) which indicates a remarkable increase in breakdown between a point and a disk for a 300-mil gap in fiber-free oil. This increase from 21 kv. to 52 kv. takes place for an increase from zero to 0.028 per cent moisture content. Dr. Hirobe then goes on to show that with ½-in. spheres 150 mils apart there is a decrease from 90 to 61 kv. for the same moisture addition.

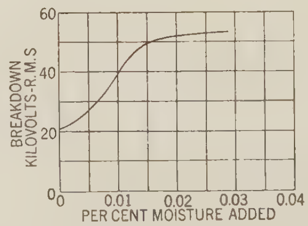

Fig. 11—Effect of Moisture on Oil Breakdown

0.3-in. Gap—needle and disk (Dr. T. Hirobe, Report No. 25, Elect. Tech. Lab., Tokyo)

5. Bibliography, 1.

A number of tests were made by the author to find the effect, not of small traces of moisture, but of large percentages of actual water in visible globule form, such as may be present when leakage of rain into apparatus occurs.

Wet Oil Tests. A series of tests was made with 3/8-in. and 5/8-in. spherical electrodes using oil into which water had been stirred. The water was introduced in finely divided spray by definitely weighed amounts and agitated thoroughly before test. By this means the water was held in suspension in very fine globules less than one mm. in diameter.

Preliminary Tests. Two 3/8-in. spheres were placed vertically in a large glass jar holding 25 lb. of oil. The gap was one inch. Various percentages of water were added and the test values were as follows:

Per cent Water	Instantaneous Breakdown	
0	56, 56, 54, 54	avg. 55 kv.
1/4 (20 cu. cm.)	60, 60, 60	avg. 60 kv.
1/2	56, 56, 56, 56, 56, 58	avg. 56.3 kv.
3/4	60, 62, 61, 62, 63, 62	avg. 61.6 kv.
1	61, 64, 59, 62, 64	avg. 62 kv.

More extensive tests were then run in a metal tank holding about 1000 lb. of oil. Percentages of water of

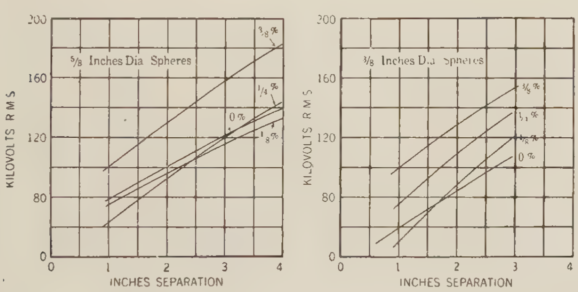

Fig. 12—Oil Breakdown Voltages—Instantaneous Averages with Various Amounts of Water Added

1/8, 1/4, and 3/8 were introduced and instantaneous breakdown tests made. It was found that 3/8 per cent was about the maximum amount of water that could be held in suspension long enough for test. Instantaneous (rapid rise) values were obtained. As usual, a great divergence of points resulted, the average of which has no great significance unless hundreds of tests are made. With only a few shots (10), these averages are inconsistent, the 5/8-in. sphere breakdown being less than 3/8-in. spheres for some cases.

Average curves for the various water contents, (Fig. 12), were plotted and seemed to indicate that addition of water may increase the breakdown of oil gaps through gradient equalization. Small amounts (1/8 per cent or less) may possibly decrease the breakdown at small separation, probably because the water is either in partial solution or so finely divided that it has the elements of a low resistance path. Increase in water content causes agglomeration and the larger globules distribute the stress like a string of condensers. This effect increases with increase in voltage.

Another effect noted at high gradients is the throwing out of water from the strongest field. This gives a clarifying action that will ultimately improve the oil considerably if breakdown does not occur before this action is complete. These statements do not contradict the usual information about standard tests on oil with a test cup having 0.1-in. separation of electrodes for here the water bridges the gap and causes failure through conduction. In the curves for 3/8-in. spheres this appears to be the case below 1½-in. with 1/8 per cent water.

The curves show a greater increase in breakdown for the smaller electrodes (3/8-in. diameter). These results differ from Dr. Hirobe's in that he could obtain no increase with spherical electrodes. It may be concluded then that with spacings several times the electrode diameter, water in globular form evenly distributed may give a higher breakdown value than commercially dry oil, behaving entirely different from the case of dissolved water in small gaps.

The curves of oil breakdown under various conditions as described in this paper show the range of values to be expected but are not intended as accurate data. Exactly duplicable results on oil are impossible. It is the purpose of this account rather to emphasize two points: First, that short-time tests are hopelessly erratic and that the time test of several minutes' duration is preferable in establishing values of use in design; and second, that the experimental data on different sizes of electrodes are related and are subject to mathematical analysis, one form of which is presented herewith.

The author gratefully acknowledges the assistance given by Mr. A. P. T. Sah in analysis of test results.

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A new high-power radio broadcast station has been opened at Stuttgart-Degerloch, Germany, operating on 379.7 meters. It is audible all over Europe and it is expected that American set owners will pick it up occasionally when natural conditions are best for receiving.

Voltage Standards for Electrical Distribution

H. B. GEAR[1]

Fellow, A. I. E. E.

Synopsis.—*This paper discusses the necessity for standardizing voltages and advocates the utilization voltage as the most logical reference base. It suggests that the ratios adopted should be uniform at all voltages. It also proposes that there should be a recognized standard for transformers in which the direction of energy flow is subject to change.*

THE necessity of standardization of utilization voltages has been recognized and accepted since the days when electric lighting systems competitive with different lamp voltages and operating frequencies constituted such an obstacle to progress that standard voltages and frequency became a commercial necessity.

Systems operating at 55 volts for lighting were discarded for 110 volts, and a 220-volt rating was chosen for use where energy was taken chiefly for power purposes.

In later years, processes of lamp manufacture were so improved as to permit the concentration of lamp output into three voltages—110, 115, and 120 volts. A steady increase in the 115-volt output, and a decrease in the relative outputs of 110- and 120-volt lamps has been in progress since that time.

Utilization voltage standards are now so well recognized that a multitude of household and motor-driven appliances have been produced in quantities and at prices which would have been totally impossible without standardization.

Utilities in many states are required by regulatory bodies to adopt a utilization voltage standard and to maintain regulation within prescribed limits above or below such standard.

This to a considerable extent, fixes the voltages in other parts of the system and makes the utilization voltage the natural base of reference.

The proposal to establish ratings which are integral multiples of 115 is a recognition of the fact that the utilization voltage is the most logical base of reference in an electricity supply system.

The utilization voltage is one which must be kept as nearly constant as possible through all ranges of load, and this is the only part of the system of which this is true.

Electricity supply systems have developed during the past quarter of a century from simple groups of distribution feeders, with one voltage level above the utilization pressure, to extended systems serving large areas with two or three voltage levels above the utilization pressure.

We are now in the process of constructing a superpower network through which these areas are being tied together, and which, in some cases, adds another voltage level to those already in service.

Each additional transformation, with its accompanying line, has added to the drop in voltage and necessitated provision of taps or other means of compensating for the added drop.

The result has been that apparatus is being operated at voltages above that for which it was designed, special windings have been specified, generators are being overexcited at certain hours, and the manufacturers have felt it necessary to call a halt for the discussion of remedial measures.

As an illustration of what is taking place in some systems, they present a diagram of voltage drops in the various parts of a system having five transformations between the generator and the consumer, with a total of about 50 per cent voltage drop between generator and consumer.

The drops chosen for illustration are average values and do not represent cases which could be found in practise involving greater drops.

It is obvious that the maintenance of voltage regulation under such conditions is a difficult problem with the best of equipment, and when there is imposed the limitation that the apparatus must not be subjected to over-voltage, the limitation will quite surely in many cases be exceeded.

Proposed Changes in Practise

The manufacturers have presented a scheme for accomplishing this by increasing secondary voltage ratings to multiples of 115 instead of 110, as at present rated.[2]

This provides a no-load pressure about 5 per cent above that given by the present standard and a full-load pressure, which offsets the drop in the transformer and delivers at full load the same pressure which is derived from transformers of the present standard at no load.

Taps are to be provided in the primary coils, as at present, to care for situations where the drop in connecting lines requires more compensation.

It is proposed that generator regulation be held within a range, from plus 5 to minus 5 per cent of standard rating.

1. Commonwealth Edison Co.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

2. *Voltage Standardization of A-C. Systems from the Viewpoint of the Electrical Manufacturer*, by F. C. Hanker and H. R. Summerhayes, A. I. E. E. Winter Convention, February, 1927.

Some Limitations of the Proposal

The example presented shows the application of the new plan under full-load conditions, where a single series of circuits is involved

The complete picture of an average system would reveal other circuits taken off at the generating station delivering energy at the generator voltage level. It would also include additional lines taken off at the 132/66/13.2-kv. levels, having various percentages of line drop, which must be taken into account in fixing the setting of transformer taps.

Inevitably there will be certain of these branches which will deliver a pressure above or below normal during certain parts of the day.

In the particular circuit shown, the pressure at quarter load would be from 10 to 12 per cent above normal at the utilization circuits, assuming that the generator pressure was reduced from 13.8 to 12.8, as proposed, during the light load period and the feeder regulator were run at full choke. In addition to this, the transformer and line equipment at the 69-kv. and 13.8-kv. levels are also operating at 10 to 12 per cent above the proposed maximum voltage ratings.

This, of course, can be avoided by the use of tap changing devices operable under load, and it is quite apparent that such auxiliary equipment must be included in the completed picture of the situation.

The necessity of having a considerable range of control between light-load and full-load conditions suggests the desirability of having as wide a range as is economically feasible in the generator voltage. It is proposed to get a range of 10 per cent by operating at pressures below normal (down to minus 5 per cent) during light load, and at pressures above normal (up to plus 5 per cent) during hours of heavy load.

This will prevent over-excitation of generators if transformer taps are connected to give the necessary boosting voltage to compensate for full-load drop. At light load periods, tap changers will be required where the total compensation in transformers is more than the combined range of generator and potential regulators.

It is proposed that the voltages above 69 kv. be left as multiples of 110.

The stage of development thus far attained may be such that it is a difficult matter to make a change now, but to those of us who have not until recent years been brought into pressures above 69 kv., it comes as something of a shock to learn that if we subject our 132-kv. equipment to any pressure above 132 kv., we are exceeding the manufacturer's rating and presumably taking a risk in operation which is not shared by the manufacturer.

The manufacturer's explanation that it is not necessary to use the multiples of 11.5 in fixing rated voltages at pressures above 69 kv. is lacking in any reasons sufficient to warrant a break of so fundamental a character in the proposed standards.

Whether the 132-kv. equipment in service has been designed for a maximum pressure of 132 kv. or not, much of the existing 132-kv. equipment is so related to the system of which it is a part that inevitably it must be subjected to pressures up to 138 kv. or higher, under the normal conditions of daily operation.

The proposed plan of adding 5 per cent to the secondary as a part of the fixed ratio of a transformer obviously can not be followed on lines where the direction of flow of energy is changed from time to time, as is often the case in tie-lines between power stations.

In such lines the transformers must meet the voltage requirements of both step-up and step-down transformers. Also, they are often so related to each other that, in order to transfer energy in the desired amount without displacing the general level of system pressure, they must be equipped with pressure taps adjustable under load.

This requires pressure taps giving a range of 15 to 20 per cent in either direction to deliver proper pressure at the bus of the receiving station.

Observance of Standards

It is obvious that if a standard is to accomplish its purpose, it must be one which will be generally recognized as practicable of application and feasible in operation.

The failure of previously adopted standards to be generally observed seems to have resulted, in part, from a lack of adaptability of apparatus to working conditions, and perhaps from a lack of appreciation on the part of some engineers of the wide range of voltage drops which have been introduced in recent years into distributing systems.

The lack of adaptability has been met as nearly as is possible by the manufacturer's proposal to increase voltage ratings to a point where they will be similar to pressures which are normally encountered in practise.

The discussion of this subject in connection with the proposed changes has and will further serve to bring a greater number of engineers face to face with the situation in a way which will be beneficial.

The adoption of standards which automatically add voltage for full-load conditions will draw attention to the necessity of providing means of preventing overvoltage at light loads.

Conclusion

Voltage standards are a basic necessity for utilization equipment and are the basis of voltage throughout the system.

The manufacturer's proposal offers a decided improvement over present standards, but should treat all voltages on a uniform basis.

There should be a recognized standard for transformers used in interconnections where the direction of flow is subject to change.

When standards have been fixed which are applicable without radical change in existing equipment, they will, no doubt, be accepted and adopted by users of equipment.

Developments in the Manufacture of Copper Wire

BY JOHN R. SHEA[1] and SAMUEL McMULLAN[1]
Non-Member Non-Member

Synopsis.—*This paper covers interesting developments in the manufacture of copper wire and contains a description of a copper rod and wire mill designed to meet the new requirements. It also includes a brief survey of the copper rolling and wire drawing art at the time the investigation was started; a summary of tests made in varying the practise in rod rolling and wire drawing, and an outline of the work done by the Bell System engineers in developing and designing new types of wire drawing machinery. The economies in floor space and plant investment due to the use of more compact and higher-speed machinery are outlined. Some of the outstanding features in plant arrangement which contribute to more efficient operation are discussed in the concluding pages.*

RAPID developments in the various branches of the communication business are constantly leading to important investigations in line with more efficiently and economically meeting the increasing demands of the service. In this connection, one of the more recent and very interesting investigations indicated the possibility of effecting substantial improvement in the process of manufacturing copper wire. Accordingly, a comprehensive study of all the factors concerned was undertaken which resulted in the construction of a rod and wire mill at Chicago, Illinois, embodying many unique and improved operations, a schematic layout of which is illustrated in Fig. 1.

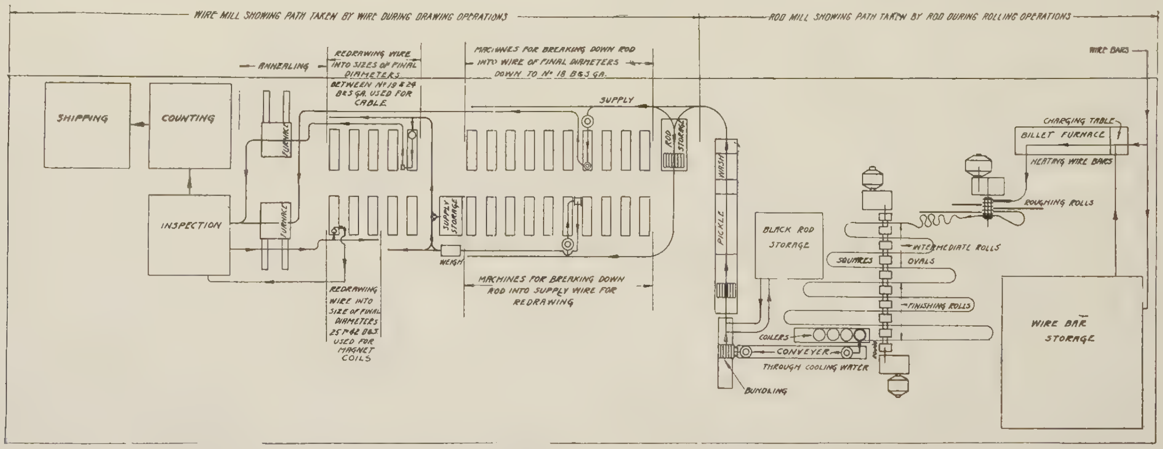


FIG. 1—SCHEMATIC LAYOUT OF WESTERN ELECTRIC CO.'S COPPER ROD AND WIRE MILL AT CHICAGO

At the outset the sources of copper and its transportation were studied and it was found more economical to ship wire bars to Chicago for conversion into wire than to locate a wire mill near some of the large refineries and ship wire to the factory. It was also considered that this plan would reduce the investment in wire during the process of manufacturing cable and telephone apparatus.

ROD ROLLING MILL

The rod rolling mill equipment consists of a billet heating furnace, a roughing mill, an intermediate mill, a finishing mill, coilers, conveyers, and pickling tubs. The mills are water-cooled and equipped with a down-draft exhaust which carries the fumes produced during the rolling operation to an air washer where the copper dust is removed before the air is discharged.

The 225-pound wire bars as received in cars from the refineries are unloaded onto skids in the train shed and transported by an electric truck to the charging end of the billet heating furnace. Here they are transferred in groups of six by a hoist to the charging table, where a compressed-air pusher moves them along through the furnace which holds 120 bars. The bars are brought up to the required temperature for rolling as they move through the furnace, which is heated by fuel oil. When the bars reach the opposite end of the furnace they are withdrawn at about 1600 deg. fahr. with a pair of tongs through the discharge door and pushed into the roughing mill one at a time. These tongs operate on a trolley suspended from a beam, which is in line with the first groove of the mill.

The roughing mill consists of three motor-driven rolls, one above the other. The bar, after passing through the first groove between the top and middle roll, drops upon feed rolls set in the floor and is returned through the second groove, between the middle and bottom roll; then raised into position and passed through the third groove, which is in the same rolls as the first pass.

1. Both of the Western Electric Company.

Presented at the A. I. E. E. Winter Convention, New York, N. Y., February 7-11, 1927.

Five passes are made in this manner until its cross-section is reduced sufficiently for it to enter the intermediate mill. As the bar enters the roughing mill it is 54 inches long and about 4 inches square. When it leaves this mill it has been rolled into an oval cross-section and is about 124 feet in length. Formerly the last pass on this mill was handled manually, and recently a mechanical repeater has been added as illustrated by Fig. 2.

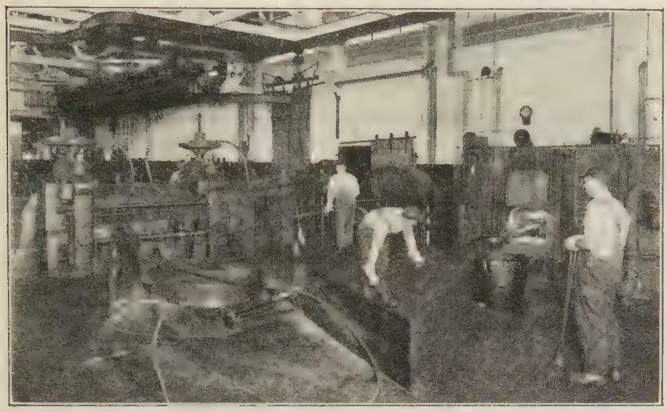


Fig. 2—View of Roughing Mill Showing Repeater on Last Pass

From the roughing mill the bar goes to the intermediate mill and is passed through the first pair of rolls. As it emerges an operator catches the end with a pair of tongs and passes it back through the next pair of rolls. The increased length between each pass at the intermediate and finishing mills is allowed to run out in a loop on a sloping iron covered floor on each side of the rolls. This catching and returning is repeated at each set of rolls until the original copper bar finally emerges a round, quarter-inch rod about 1200 feet long. This last pass goes through a guide pipe into a coiler, Fig. 3. The reductions in cross section are illustrated by Fig. 4. An appreciable amount of copper oxide scale is carried off with the cooling water, and deposited in a reservoir from which it is later salvaged.

Fig. 3—View of Intermediate and Finishing Mills and Coilers

The coils are automatically unloaded from the coilers on to a conveyer, which carries them through cooling water in a tank underneath the floor. Eighty-two seconds after entering the roughing mill the bar is a coil of ¼ in. rod ready to proceed on its way to the pickling tanks. The mill has a capacity of 70,000,000 pounds annually on a 48-hour per week basis.

While the diagram and illustration of the intermediate and finishing mills indicate for simplicity that the rod follows only a single path, in actual operation sufficient material is kept in the mill practically to maintain at least two rods in the finishing mill. This is illustrated graphically by that part of Fig. 5 which covers the finishing mill. Referring to line A–A^1, 11 reductions are being made in this mill at the same time, two for each of the first four pairs of rolls and three on the final rolls. At this period in the cycle of operation 800 h. p. is required.

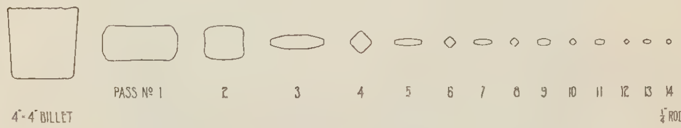


Fig. 4—Rod Mill Reductions—4-in. x 4-in. Billet to ¼-in. Rod

When the rod mill was started eighteen passes were in use by several of the most modern mills. A sixteen pass arrangement was adopted for the new mill, in which the metal was subjected to a greater amount of work in the earlier passes when it was hot. Later, as a result of further study, fourteen passes were adopted. Fig. 6 illustrates graphically the per cent reduction effected at each of the above passes. The reductions plotted as the abscissa are in terms of reduced area in cross-section at each pass and the passes reading from left to right are plotted as ordinates.

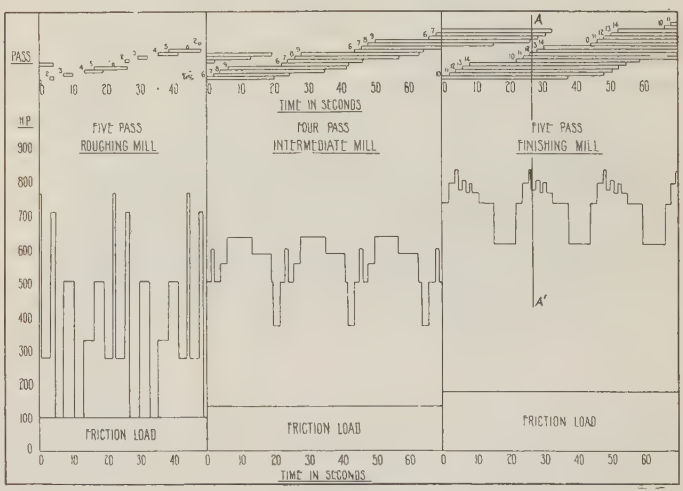


Fig. 5

It is obvious that careful planning must be done in changing the number of passes in a mill in order not to exceed the safe working capacity of the mill rolls and stands. Such calculations have been made using roll-

ing mill formulas[2]. Based on the more sturdy mill installed at the Chicago plant the first four passes of the eighteen pass arrangement would operate at about 82, 100, 105 and 90 per cent of the safe working load of the mill. These same passes calculated on the basis of the sixteen and fourteen pass arrangement operate at 86, 87, 90, 85 and 96, 96, 90, 90 respectively. This

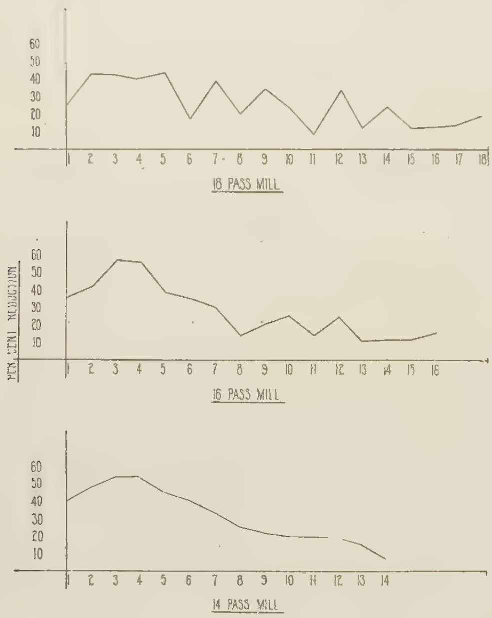


FIG. 6

indicates that a further reduction may be made in the number of passes in the mill provided other features are improved; *i. e.*, roll adjustment.

RELATION BETWEEN WORKING AND PHYSICAL PROPERTIES

It has often been stated that the more passes (*i. e.*, the more gradual working) given the copper, the better the physical qualities of the rod. Actual tests (see Table I) made on representative lots of ¼-in. rod fail to confirm this impression.

TABLE 1

Lot	Number of passes	Elongation per cent	Tensile strength lb. per sq. in.
1	18	35.8	33,752
2	18	40.0	31,445
3	16	37.1	32,468
4	16	41.0	32,160
5	14	42.0	32,391
	Average of 5 lots	39.5	32,243

The averages indicate that a fourteen-pass rod is superior in elongation, and better than the total average in tensile strength.

CLEANING OF ROD

When the coils emerge from the tank through which the rod coiler apron conveyer passes, they are cool enough to handle and after being tied with wire, several are lifted together by a monorail crane, and placed for thirty minutes in a pickling tank containing from 5 to 10 per cent free sulphuric acid, in order to remove the black oxide caused by oxidation of the hot copper in the air during rolling. The solution is maintained at approximately 120 deg. fahr., and the copper content varies from one to three grams per 100 cu. cm. Experiments have shown a difference of less than 10 per cent in pickling time between the minimum and maximum acid used, the greater solubility being obtained from the weak solution. Actual results obtained were checked with Sidell's Table of Solubilities (See Fig. 7). While a variation from the minimum to maximum acid concentration does not materially affect the pickling time, a variation in temperature has a decided effect as may be seen from Fig. 8.

ELECTROLYTIC PLANT

Fig. 9 shows a plant in which the copper is reclaimed from the pickling bath at about the same rate as it is absorbed. This is accomplished by electrolytic deposition according to principles worked out and practised in the large refineries which produce electrolytic copper.

The electrolytic system operates best with a minimum

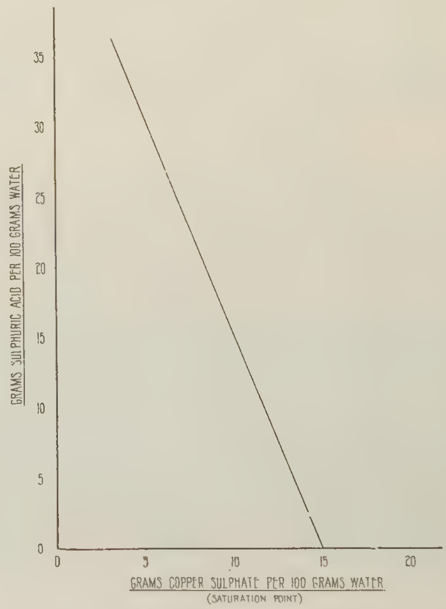


FIG. 7—SOLUBILITY CURVE OF COPPER SULPHATE IN A SULPHURIC ACID SOLUTION (TEMP. 25 DEG. CENT)

Reference Table of Solubilities by Sidell, *Chem. & Met. Eng.*, Vol. 21, p. 181-2, 1919.

content of about 1 per cent copper and 5 per cent acid and a maximum of 3 per cent copper and 10 per cent acid. The copper and acid contents are kept as low as practicable to minimize "carrying out losses"[3] during the pickling operation. About 775 pounds of acid, and 430 pounds of copper are recovered per day

2. "Pass Limitation in Rolling Mill Practice," *Machinery*, July, 1918.
"The Theory and Practise of Rolling Steel," Wilhelm Tafel.

3. Pickling solution carried out when coils are removed from tank.

from the electrolyte. The anodes are operated at a current density of five amperes per square foot with a rate of deposition of about 0.00261 pound of copper per ampere-hour.

The heat generated in the plating tanks under normal operating conditions maintains a minimum

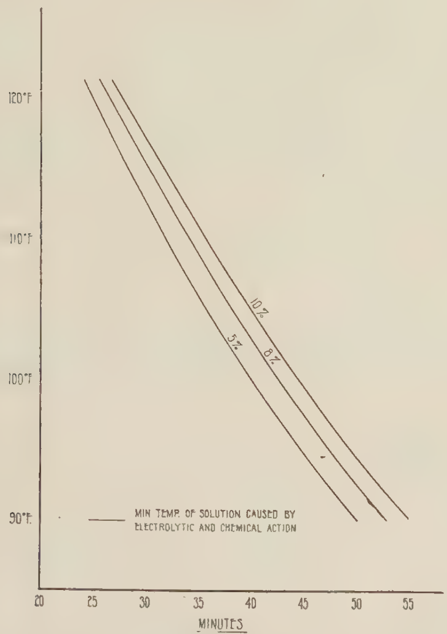


Fig. 8—Rate of Pickling at Practical Acid Concentration

Max. temp. without excessive evaporation and fumes

temperature of about 90 deg. fahr., throughout the acid system, and the maximum temperature is obtained through steam heating coils in the pickle tanks. Faster pickling would result from the use of higher temperatures but experience has shown that the additional steam and

Fig. 9—Electrolytic Recovery of Copper From Rod Mill Pickling Solution

gas released above 120 deg. fahr., results in unsatisfactory operating conditions.

The coils of rod after pickling are thoroughly washed with lake water[4] at a pressure of about 70 pounds per square inch to remove loose copper dust and acid, and then immersed in an alkaline fat solution to neutralize any trace of acid and to provide a protective coating against oxidation until converted into wire.

Wire Mill

The coils, after being pickled and washed, are carried by monorail cranes to the wire-drawing machines where they are converted into wire of the desired size. The dies used in the heavy wire drawing machines are pulled into place at the starting end of the coil of rod on a die

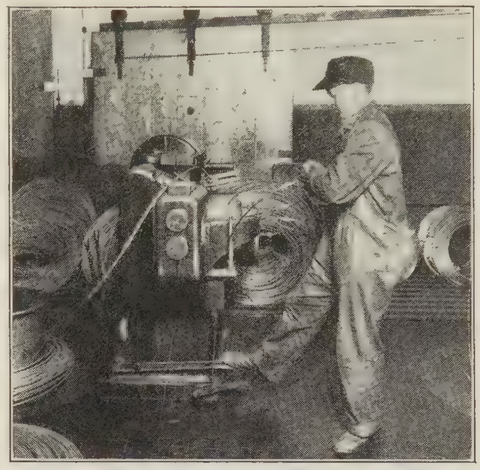


Fig. 10—Heavy Wire Die Stringer

stringing machine (Fig. 10). The coil, with dies strung into position, is then placed in a heavy wire-drawing machine.

The heavy gages of wire, such as line wire, are drawn with one set-up on a heavy wire-drawing machine;

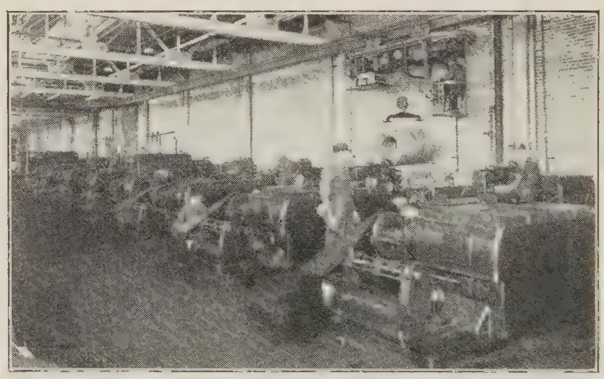


Fig. 11—Battery of No. 1 Wire-Drawing Machines

medium sizes, used in lead covered cable, are made by taking the wire as it comes from the heavy machine and redrawing it on the intermediate machine; and finer sizes, commonly known as magnet wire sizes, are produced by redrawing intermediate sizes.

The present capacity of the wire mill is approximately 42,000,000 pounds annually, and the sizes range from 0.165-in. line wire to 42 B. & S. (0.00247-in.) gage magnet wire. Provisions have been made in the construction of the building and its foundations so that the mill may be expanded in capacity when needed.

The No. 1 or heavy wire-drawing machine shown by

4. Lake water is relatively free from mineral salts which would corrode the rod and affect the wire drawing compound.

Figs. 11 and 12 draws line wire, heavy toll cable sizes, and supply wire for the loop cable wire machines. This ten-die machine with its auxiliary equipment and operating area occupies a floor space of 270 sq. ft. and runs at 1500 to 2000 ft. per min. as compared with 470 sq. ft. for a commercial nine-die machine running about 1000 ft. per min.

A battery of these machines costs much less than an installation of commercial machines of the same capacity,

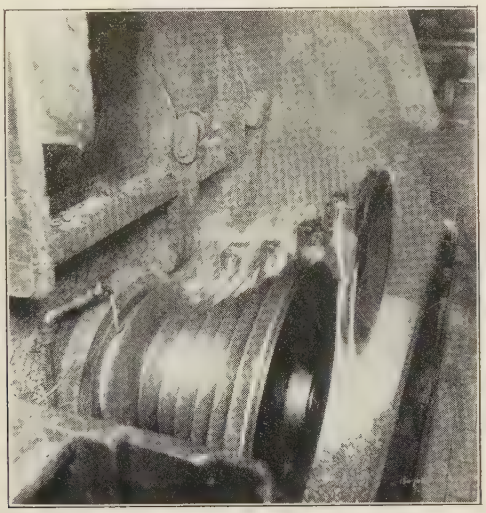


Fig. 12—Close-Up View of No. 1 Machine

and in addition, effects a considerable economy in floor space.

The commercial types of ten-die intermediate machines for drawing cable wire require about 130 sq. ft. of floor space as compared to 90 sq. ft. for a twelve-die multiple head machine. The former is a single-unit machine and the latter a four-unit machine operating at twice the speed and capable of producing

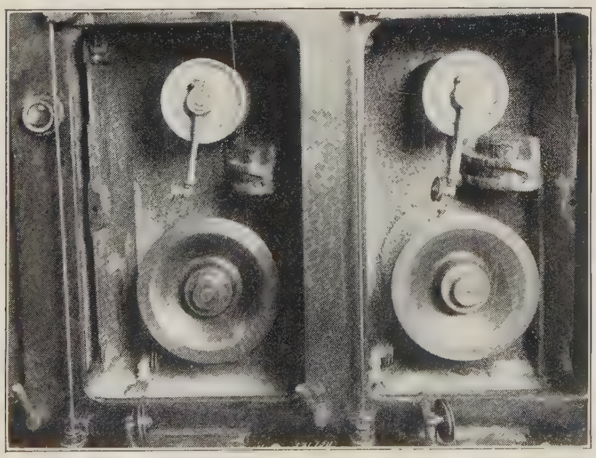


Fig. 13—Close-Up View of Units of No. 3 Wire-Drawing Machine

about five times the output of the commercial equipment. This new multiple unit machine costs more than regular equipment, but considering the four units, the cost is materially less per unit, and very much less on an output basis.

The magnet wire-drawing machine is a high-speed twelve-die multiple head machine of eight wire drawing units, occupying 90 sq. ft. of floor space including the operating area. A close-up view of two heads of this machine is shown in Fig. 13. Fifty-one sq. ft. of floor space are required for a single unit (one head) commercial machine of the same die capacity. The saving in investment in this case is even greater than for the heavy and intermediate types of machines. The use of these compact machines and overhead monorail equipment for transporting material instead of using trucks with large aisles has permitted the installation of the wire drawing mill in less than one-fourth of the building area which would have been required if commercial equipment had been purchased.

General Plant Features

The present connected load of the motors in the rod and wire mill is about 6000 horse power for which it was necessary to enlarge the factory power plant.

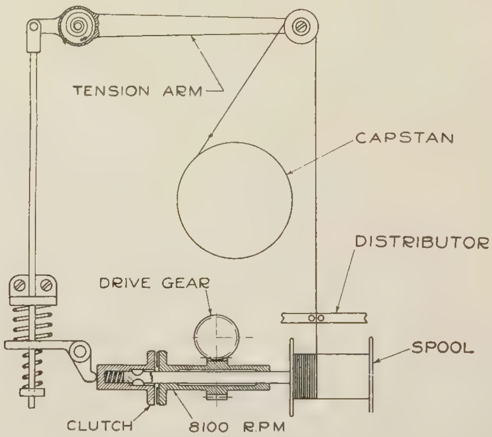


Fig. 14—Automatic Tension Mechanism of No. 3 Wire-Drawing Machine

A 700-ft. tunnel connects the power plant with the rod and wire mill in which are laid pipes for carrying hot and cold water, steam, gas, and air and lead covered power cables.

The basement under the rod mill houses the electrolytic equipment, control boards for the roughing and intermediate mills, pumps for cooling water, and exhaust fans connected with an air washer for removing the fumes from the rod mill. A tunnel which passes beneath the intermediate and finishing mills connects with a room which houses the drives for the four rod coilers, the coiler control boards, the finishing mill control board, and the main power panel. In the wire mill basement are six large tanks which hold the compound used to lubricate and cool the wire-drawing dies. This compound is supplied under pressure to the wire-drawing machines on the floor above and returns by gravity.

All the wire-drawing machines are controlled by push buttons mounted on the machines, which connect with compensators in the basement. The 100-h. p. motors

driving the large wire-drawing machines are mounted in a tunnel and are connected to the machines above by chain drive.

This arrangement permits accessibility for maintenance of the electrical equipment with a minimum of interference to production, prevents the wire-drawing operators from having access to the electrical equipment and reduces accident hazard to a minimum.

Developments in Wire-Drawing Equipment and Methods

The rod and wire mill just described was designed following a comprehensive survey of wire-drawing processes and equipment used in this country and abroad. In connection with these studies, extensive laboratory investigations were undertaken relative to the characteristics of different types of commercial machines especially from the standpoint of operating efficiency, investment and floor space requirements. As a result of these investigations, it developed that marked improvements could be effected if wire could be produced commercially at higher machine speeds and with more compact machine equipment.

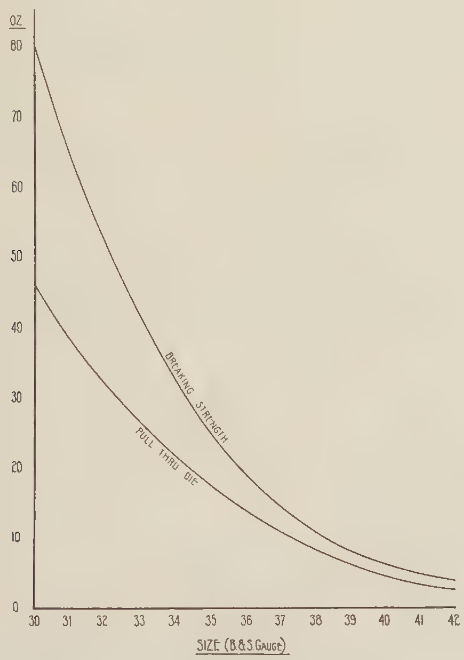


Fig. 15

While the design of the drawing mechanism in the new machine was very important, it was also essential that the finished wire be taken up on spools instead of coils. After considerable experimental work, a sensitive take-up device was developed to permit spooling at a constant drawing speed.

This spooling mechanism is illustrated by Fig. 14 in which the spool spindle is driven by a slipping clutch member controlled through a tension arm, on which an idler pulley is located over which the wire passes on its way from the drawing capstan to the take-up spool. The take-up mechanism rotates the core of an empty spool at a speed synchronous with the speed of the wire as it leaves the drawing capstan. As the spool fills and the speed tends to increase, the wire on the tension arm tightens and compresses the tension arm against a spring adjusted for the proper gage of wire. This in turn reduces the pressure of the clutch driving the take-up spindle permitting the spool of wire to readjust its speed.

This device is extremely sensitive as illustrated in the drawing of No. 42 B. & S. wire at 2000 ft. per min., in which case the control arm must be adjusted to operate between 90 and 150 grams, since the pull required is 87 grams and the breaking strength of the wire is 170 grams. This device is so flexible that it can be adjusted to a drawing tension of from 9 pounds for No. 25 wire to 3 ounces for No. 42 wire. Fig. 15 illustrates its operating range on wire sizes No. 30 to No. 42, showing the gradual narrowing of the limits as the sizes decrease. A larger machine used for drawing loop cable wire from No. 18 to No. 30 B. & S. gages contains a similar mechanism.

The use of this sensitive device and a clutch which would slip without overheating as the spool filled' together with improvements in the wire drawing compound and the shape and quality of the diamond dies later described, permitted the drawing of wire at speeds ranging from 2000 to 3000 ft. per min.

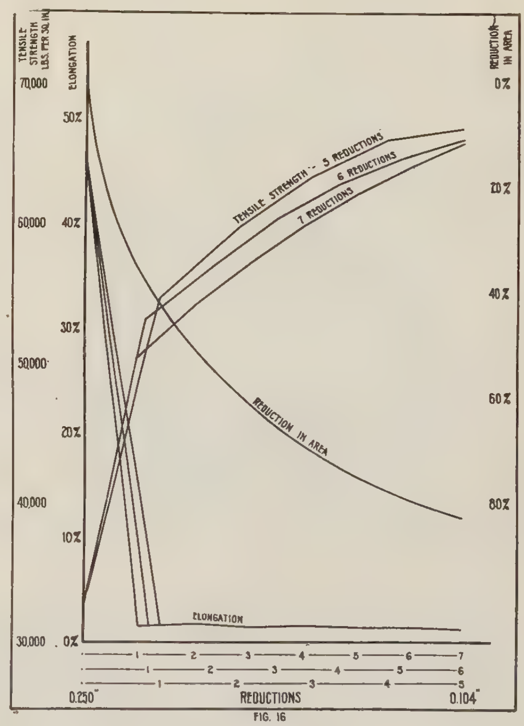


Fig. 16

Wire Drawing Compound

At low speeds it was discovered that the compound for lubricating wire-drawing dies required little attention but as the speeds were increased the necessity for close analytical control was evident. The compound con-

sists of an emulsion of soap, tallow, and water, the percentage of the soap and tallow being varied depending upon the size of wire and type of machine on which it is used.

It is important that the degree of emulsification[5] be carried far enough to break the tallow into particles about one micron in diameter, so that the material will stay in suspension in the water. If the tallow content is increased beyond a certain point it holds

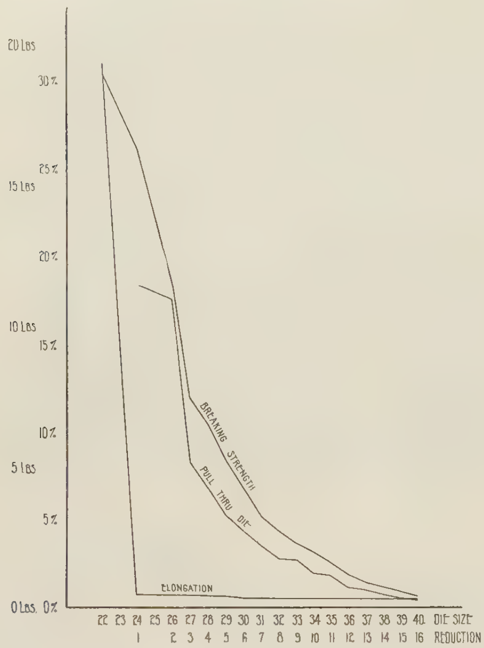


Fig. 17

in suspension in the solution a large amount of the copper dust which flakes off in a very fine state during the wire-drawing operation and this clogs the dies and causes breakage during the wire drawing. Ordinarily this copper dust settles out of the solution while in the large cooling tanks and a considerable amount is salvaged in this manner.

Effect of Drawing on Copper

Tests were made to determine if the drawing of the smaller cable and all magnet wire sizes[6] in Brown & Sharpe (A. W. G) steps was obtaining the maximum reduction possible per die. These tests showed it was feasible to make much heavier than A. W. G. reductions at the first draft when annealed wire or soft copper rod was being drawn. It also showed that the elongation[7] of the rod or annealed wire was rapidly reduced to the drawing minimum after the first pass, and remained at that point throughout the process.

Fig. 16 illustrates the effect of a five-die reduction on elongation and tensile strength. It may be seen that the elongation drops very rapidly at the first die when a reduction in area of about 42½ per cent is made, and the tensile strength increases rapidly because of the cold working of the metal.

This same figure shows the tensile strengths obtained when five-, six- and seven-die reductions are used to produce line wire of 0.104 diameter from the same supply. Here the elongation loss is about the same in each case, but the tensile strength is greater with the heavier reductions. The five-die arrangement is satisfactory according to the results shown on the curve, but the heavy reduction at the first die often results in rough or slivered wire. The six-die arrangement, therefore, gives the greatest factor of safety. The seven-die arrangement is less satisfactory since the elongation and tensile strength in the finished wire are so close to the requirements.

The use of A. W. G. reductions for the finer sizes of cable and magnet wire provides flexibility, since a change in the size of wire can be accomplished simply

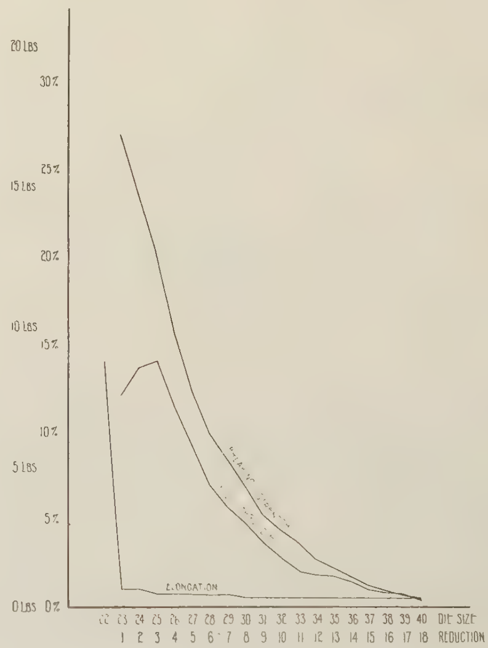


Fig. 18

by increasing or reducing the number of dies used. Tests were conducted to determine the gain by using heavier reductions and annealing the wire before redrawing, and Fig. 17 shows the increased reduction possible at the first die when the metal is plastic. In this test, an annealed No. 22 gage wire of 31 per cent elongation was reduced to No. 24, two gages, in one draw. The soft copper permitted a double reduction at the first die, but the elongation dropped during the operation to less than 1 per cent; the second reduction on this test was from No. 24 to No. 26 gage and the pull

5. "The Theory of Emulsions and Emulsifications," W. Clayton.

6. A. W. G. ("American Wire" or "Brown and Sharpe" gage) reductions are not used in converting the rod to line wire; these are generally specified in B. W. G. and N. B. S. gages.

7. See Figures, 16, 17, 18, and 19 showing the elongation of the rod or wire dropping to about 1½ per cent at the first die reduction and remaining practically constant.

required for this pass practically coincides with the breaking strength of the wire. Wire drawing under such conditions is impractical because the annealing operation is much more expensive than drawing hard wire from No. 22 to No. 24 in two passes.

Fig. 18 illustrates the results obtained when drawing annealed wire with A. W. G. reductions. The large margin of safety between the pull required and the breaking strength of the material again disappears after two reductions. Fig. 19[8] illustrates practical

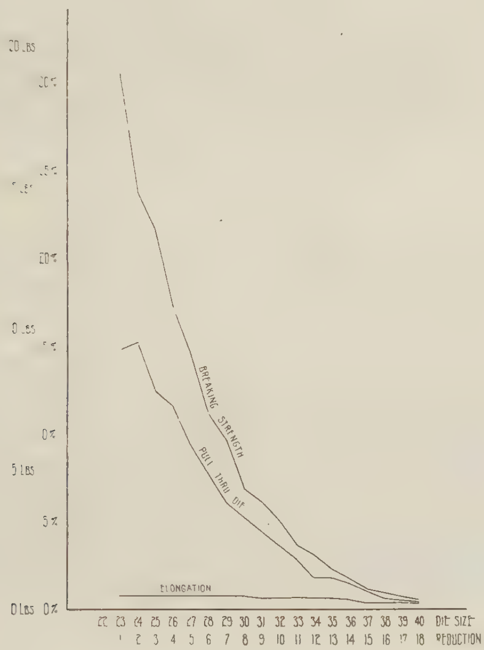


Fig. 19

drawing conditions adopted for drawing wire to finished sizes without annealing during the process.

Chilled Iron Dies

The dies used for drawing heavy wire are cast with a tapered hole from chilled cast iron and reamed to the desired size. When the die wears too large for a particular size of wire, it is reamed to a larger size and used in that manner until the dies goes above the maximum size used. These dies, shown in Fig. 20 are used for drawing line and heavy gage wire for which the cost of diamond dies would be excessive. Many alloy steel dies have been tested as substitutes for chilled iron dies for copper wire drawing, but so far have failed to replace them, due to excessive cost. For the wire sizes smaller than No. 16 down to as fine as No. 42 B. & S. diamond dies as described below are used.

Diamond Die Study

It was necessary to make an extensive study of the manufacture of diamond dies because dies through which wire could be satisfactory drawn at low speeds failed to draw to gage and without excessive breakage of the wire as the speeds were increased. At this time practically all commercial diamond drilling was done in Europe, Belgium being the hub of the diamond cutting industry and the art was new to this country. The diamonds generally used for wire drawing dies are obtained from South Africa[9], Australia, and Brazil, and made into diamond dies in Europe.

In view of the difficulty of obtaining dies for drawing wire at high speeds and the large investment in dies required for the proposed wire mill, it was decided to undertake a laboratory investigation of the manufacture of diamond dies suitable for drawing cable and magnet wire.

It was found that the dies suitable for high-speed wire drawing required a differently shaped approach, a better polish, and a shorter land[10] than used for low-speed drawing. In addition the origin of the stone, the shape of the diamond and its setting are all very important because of the internal strain to which the die is subjected during the drawing operation.

It has not been possible to definitely establish any

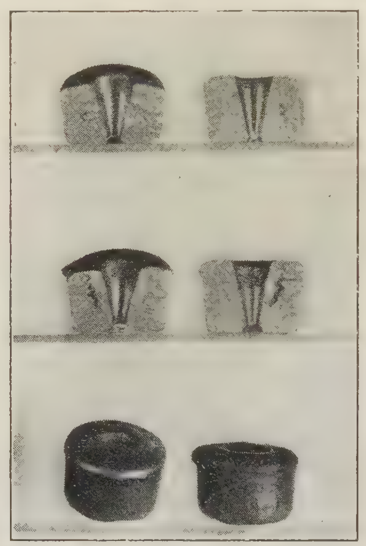


Fig. 20—Dies Used for Drawing Line and Heavy-Gage Wire

quantitative relationship as to the effect of high-speed drawing on the wear of dies except that about the same number of million feet of wire may be expected from a properly lubricated die irrespective of the drawing speed. Under such conditions, the high-speed die naturally runs a shorter time, but length of life is not

8. Slight irregularities in the curves are due to variations from the mean in the diameters of the dies used during the tess.

9. The South African and Australian diamonds are the more suitable for wire drawing. There are two types of the former, the smooth brown premier which is not suitable for dies because of its tendency to crack and split, the other commonly known as the Jager, a product of the Jagerfontein mines. These stones, very irregular in contour and light gray to black in color, are most suitable for dies. The Australian diamonds are gray to brown to almost black in color and can be distinguished from the Jager. Many of the Brazilian diamonds are a dark gray similar to graphite in color and not being translucent are difficult to inspect for seams, cracks or inclusions.

10. See Figure 21.

the important factor; tonnage of a satisfactory quality with a minimum plant and labor investment is the prime consideration.

Fig. 22 shows a diamond before drilling, a stone drilled and lapped, ready for mounting, and a die in

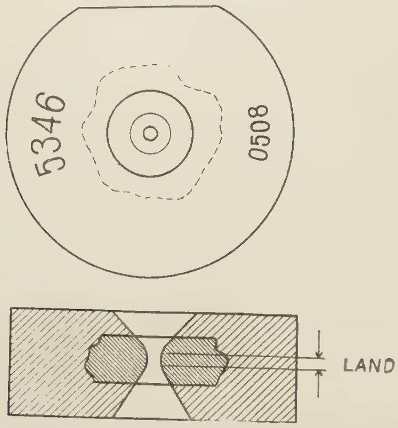


Fig. 21—Diamond Wire Drawing Die

the final mounting ready for use. Fig. 21 gives an outline of the shape of the working surfaces of a wire-drawing die.

Annealing

Hard copper wire is obtained by using the wire as it comes from the wire drawing machine. This same wire may be softened by annealing, or medium-hard wire can be produced by annealing hard wire at such a point in the drawing operations that the final draws will give the desired degree of hardness[11].

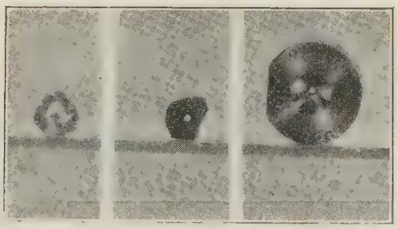


Fig. 22—Showing Diamond Before Drilling, Drilled and Lapped Ready for Mounting and Die Ready for Use in Final Mounting

In a recent commercial type of annealing furnace, Fig. 23, wire may be bright annealed, but it requires a drying operation in order to remove the water through which it passes in leaving the furnace. The retorts of these furnaces are water-sealed and filled with steam to exclude the outside atmosphere, which would discolor hot copper. To obtain bright wire, it is passed under water into the retort to exclude the air and is generally taken out and cooled under water or in an atmosphere of steam or gas, which excludes oxygen until the wire is relatively cool.

11. "Experiments in the Working and Annealing of Copper," F. Johnson, *Journal Institute of Metals*, Volume XXVI, No. 2, 1921.

A special steam-seal annealing furnace for small spools of wire was developed on an experimental basis

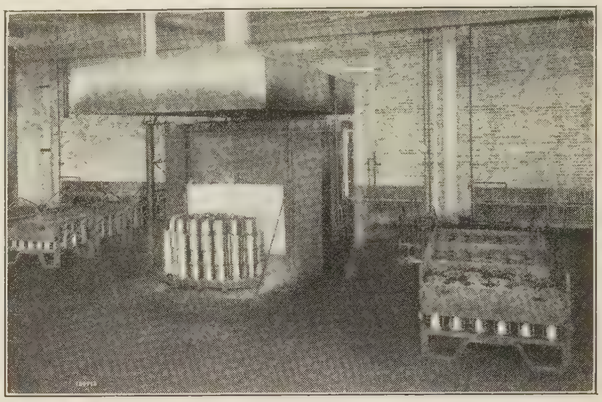


Fig. 23—Water-Seal Annealing Furnace

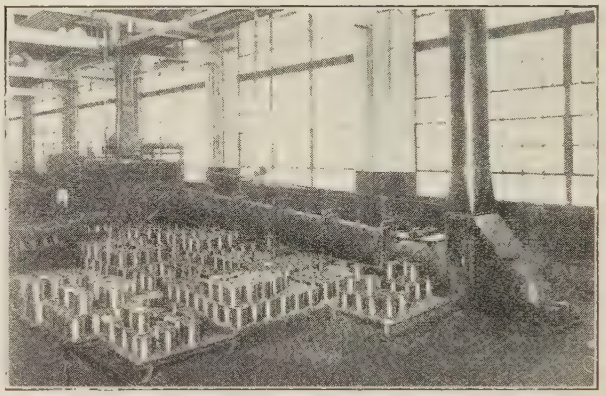


Fig. 24—Steam-Seal Annealing Furnace

Fig. 25—Photomicrographs of Wire Bar (Magnification 33)

A. High Set—Oxygen, 0.035 per cent
B. Level Set—Oxygen, 0.05 per cent
C. Low Set—Oxygen 0.12 per cent

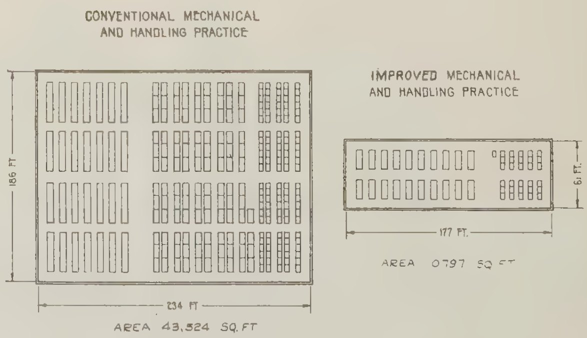


Fig. 26—Diagram of Wire-Drawing Plant

from which the wire was obtained bright annealed and free from moisture. In this furnace the spools were submerged in water to displace the air, raised into the charging end which was under water, thence to the muffle to be heated and then along a cooling tube to the discharge opening. Air was excluded from the retort and cooling chamber at the discharge end by means of a steam jet.

The success of the small furnace led to the construction of a larger machine (Fig. 24) for annealing cable wire on spools. The spools are placed in perforated metal baskets which are charged into the furnace at a specified time interval, pushing each other through the retort and along the cooling tube to the discharge end.

Inspection of Raw Material and Finished Product

Wire bar made from electrolytic refined copper is used as a material in the manufacture of wire. This material is practically free from silver and other elements which ordinarily exist in the ore, and which have a detrimental effect on the electrical or physical properties of the finished product. A small percentage of silver[12] seriously affects the annealing qualities of the wire. Traces of other impurities have a very detrimental effect on the wire drawing properties. During the refining process, the molten bath is oxidized in order to carry off the foreign material in the form of slag, and it is very important that the oxygen content be later reduced to a very small point if bars of proper set are desired. Fig. 25 shows three photomicrographs of wire bar containing varying amounts of cuprous oxide[13]. Ordinarily the surface condition on top of the bar is a good index of the oxygen content. If the bar is level set or slightly convex on top, it is usually a satisfactory material. If it is low set or concave it usually contains a large amount of copper oxide, which caused the metal to shrink in solidifying[14]. When excessive shrinkage occurs it has an adverse effect during the rolling operation.

The finished wire is inspected for dimensional limits, tensile strength, elongation and surface condition. Limits for 42 B. & S. gage wire 0.002475 are 0.00245 minimum and 0.0025 maximum.

Conclusion

The establishment of this industry as a part of the plant at Chicago represents the combined effort of a large number of inventors, engineers, designers, and mechanics. While the actual plant was built within a comparatively short period, the advances which have been made in the art represent several years' effort. Briefly, the development of compact and high-speed wire-drawing machines has required a much smaller investment in buildings and equipment as compared with a plant of the same capacity using commercial equipment. A comparison of the relative floor area, based upon the conventional and the improved types of wire drawing equipment, is illustrated by Fig. 26. The supervisory force in charge of the operation of this new mill must be given a considerable share of the credit for its successful operation.

12. "Effects of Silver on the Recrystallization Temperature of Copper," Caesar and Gerner, A. S. M. E., Volume 38, 1916.

13. "Microscopic Structure of Copper," H. P. Pulsifer, Mining and Metallurgy, January, 1926.

14. "Copper Refining" Lawrence Addicks.

"Metallurgy of Copper" H. O. Hofman.

COOPERATIVE STUDY OF RADIO FADING

Radio progress depends upon an increasing knowledge of the vagaries of radio-wave transmission. Radio transmitting and receiving devices have been highly perfected, but received signals are still subject to variations and distortions. In order to secure data on the causes of these variations, the bureau invited a number of university and other laboratories to cooperate in their study. The principal work was the conducting of special radio transmissions from broadcasting stations, during which all the laboratories made simultaneous graphical records of fading.

This work shed a great deal of light on the nature of radio-transmission phenomena. From the results it was possible to determine the dependence of fading on distance, frequency, and other conditions. The fluctuations known as fading are extremely great, and, in addition, there is a wide variation in the average field intensities received from night to night. However, there was discovered one type of regularity in the average intensity of fading signals which had not previously been suspected. This was a definite relation of the ratio of average night to day intensity. This relation was found to have important theoretical bearing in explaining the difference between day and night time transmission conditions.

The results lent new corroboration to the hypothesis that fading and nighttime transmission of radio waves to great distances are due to the action of a conducting surface high in the atmosphere. This hypothesis had been published by the bureau in 1921, as a result of some fading observations made at that time. The characteristic fading observed at considerable distances is found to be caused by variable absorption in the upper atmosphere, and the relatively fast fading is largely the result of interference between the wave transmitted along the ground and the wave which has traveled via the upper conducting surface in the atmosphere. One interesting result is that there was little correlation found between radio reception conditions and weather.

This work was accompanied by a number of special studies. Measurements made upon received signals at very high frequencies (short waves) showed that the transmission was, in general, irregular, and that the portions of the day for best transmission were markedly different for different frequencies.—*Tech. News Bulletin.*

Stroboscopic Method of Testing Watthour Meters

BY H. P. SPARKES[1]

Member, A. I. E. E.

Synopsis.—*This paper deals with an optical method applied to watthour meter testing. The method as presented overcomes, to a great extent, personal error, and lessens the time required through the use of measured light impulses. It gives instantaneous comparison between watt-seconds on two measuring devices.*

The objects of this method are:

First: To reduce the time of laboratory tests, acceptance tests and re-calibration.

Second: To reduce personal error, and to increase the accuracy of the test.

Third: To provide a device that gives precision instrument accuracy.

Fourth: To make time devices in precision tests unnecessary.

Introduction

The present-day ideal of calibrating and checking watthour meters requires maximum accuracy with minimum loss of time. This paper deals with a device that reduces the time required per meter and increases the accuracy of the test by eliminating the human error factor and giving large indications of small increments of speed. In reality, this device is a wattmeter with a light vernier scale for measuring watt-seconds and giving instantaneous indications of meter speed.

This device measures watts with a high degree of precision, then transfers the measurement into a corresponding number of light impulses per second. The meter disk is calibrated in watt-seconds by means of marks placed on the circumferential edge of the disk.

In operation, a load is placed on the meter and the light impulses are then synchronized with the lines on the disk. When thus synchronized the markings appear to be stationary. The error of the watthour meter is then read on a balance indicator. By this method the accuracy of the meter is checked.

For calibrating the watthour meter the frequency of the light impulses is kept proportional to the meter load. Then if the meter is running at an incorrect speed, the markings on the disk will appear to move. For high speed they will progress and for low speed they will retrogress. To calibrate the meter it is adjusted until the markings appear stationary.

This apparent standing still and moving of the disk markings is the stroboscopic effect, which is more or less familiar to most engineers.

Principles of the Device

To illustrate the principles, it may be well first to refer to Fig. 1 which shows a portable outfit with hand adjustment only for controlling the frequency of the light impulses. This outfit consists of two principal parts. The first is the light-impulsing machine consisting of a driving motor on whose shaft are mounted a commutator which makes and breaks the light circuit and a magneto whose voltage varies as its speed. A hand rheostat is used to adjust the motor speed. The second part is the balance indicator. This is similar to a polyphase wattmeter except that one element is replaced by a standard d'Arsonval d-c. voltmeter element. In operation the two elements mechanically oppose or buck each other. To the a-c. element is connected the same load that passes through the watthour meter under test. The d-c. element is connected in series with the magneto and its torque is proportional to the speed of the motor or the frequency of the light impulses.

When a meter is to be checked it is connected to a load as shown in Fig. 1. The speed of the motor is then adjusted by the hand adjuster until the markings on the meter disk appear stationary when viewed by the impulsed light. The error in meter speed is then read from the balance indicator.

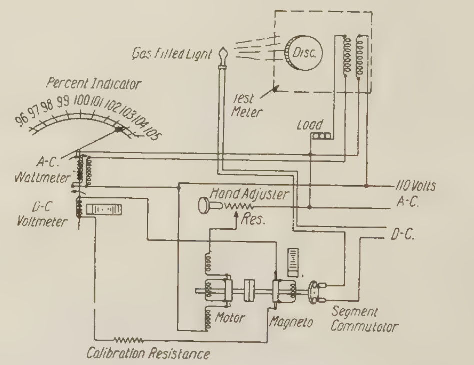


Fig. 1—Connection Diagram for Portable Stroboscopic Watthour Meter Checker

May be used with calibrator by means of transfer switches not shown.

The functioning of the parts may be explained as follows: At the given load the meter revolves at a certain speed. This load also causes a certain torque on the a-c. element of the balance indicator. The speed of the motor is adjusted to synchronize with the disk markings. This causes the magneto to generate a certain voltage and this acts on the d-c. element of the balance indicator. If these two elements exactly balance, then the meter is running at the correct speed for the given load. If the meter is running too fast, the frequency of the light impulses must be increased to bring them in synchronism with the meter disk. On

1. Westinghouse Electric & Mfg. Co.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

increasing the light frequency the speed of the magneto is increased which increases its voltage and this increases the torque on the d-c. element of the balance indicator causing it to read high.

Conversely if the watthour meter is running too slow, the balance indicator will read below normal.

The foregoing illustrates the method of checking the accuracy of a meter. For calibrating, the method is varied as follows: The speed of the motor is adjusted so that the balance indicator reads 100 per cent speed or no error. Then if the watthour meter is running

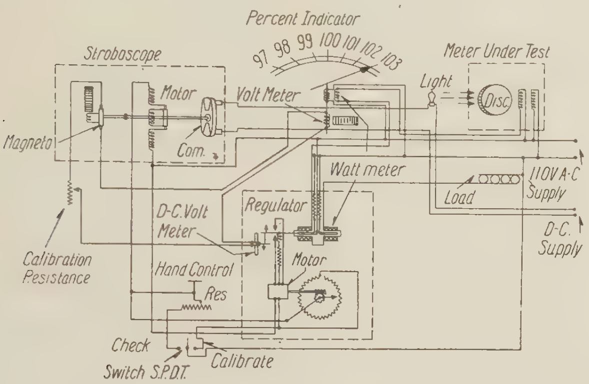


Fig. 2—Connection Diagram of Stroboscopic Watthour Meter Calibrator and Checker

at an incorrect speed the markings on the disk will appear to rotate. There will be progression for a fast meter and retrogression for a slow meter. Adjustments may then be made on the meter until the marks appear stationary which will mean that the speed is correct.

Laboratory Form of the Device

The job of holding the balance indicator at the point of 100 per cent speed is performed by hand in the portable device but in the laboratory form of the device this is performed by an automatic regulator. Such a regulator is necessary where a high degree of accuracy is desired as it eliminates the necessity of maintaining a balance by hand. This regulator is shown in Fig. 2 which is a design of the laboratory device and connections. The regulator consists of three main parts. The first part is a wattmeter of the Kelvin-balance type which takes the same load as does the tested watthour meter. The second part is a standard d-c. voltmeter of the d'Arsonval type. This d-c. meter is actuated by the magneto already mentioned and its torque is proportional to the speed of the stroboscope motor. These two elements are mechanically connected in opposition and by means of contacts and a reversing control motor (the third part), they control the series resistor of the stroboscope motor. By this arrangement the speed of the stroboscope motor and the frequency of the light impulses are maintained proportional to the watthour meter load.

The foregoing is a general description of this device and in the following paragraphs further descriptions will be given of the four main parts, (1) the watthour meter to be tested, (2) the regulator balance, (3) the light impulsing machine and (4) the balance indicator.

The Watthour Meter to be Tested

The watthour meter to be tested must have its disk marked with a number of equally spaced lines, usually 300. Fig. 3 is an illustration of a commercial five-ampere, 115-volt watthour meter with marks on the edge of the disk. These marks are carefully graduated so that there are 300 equidistant marks filled with black. However, the black may be omitted, as the lines are visible and are much sharper without the black.

Disks for new meters and old meters may be marked with precision at a very low cost. The major expense will be in changing the disks. Standard disks may be used; but the graduations must be perfect and of the proper number to match the range of speed of the calibrator.

The Light-Impulsing Machine

The light-impulsing machine is composed of a high-speed series motor (a-c.), a commutator and brush ring, and a speed indicating magneto, all of which are mounted on a heavy bed plate. The shafts are coupled with a high-speed pin coupling of large diameter, the flexible portion being mounted on the motor shaft.

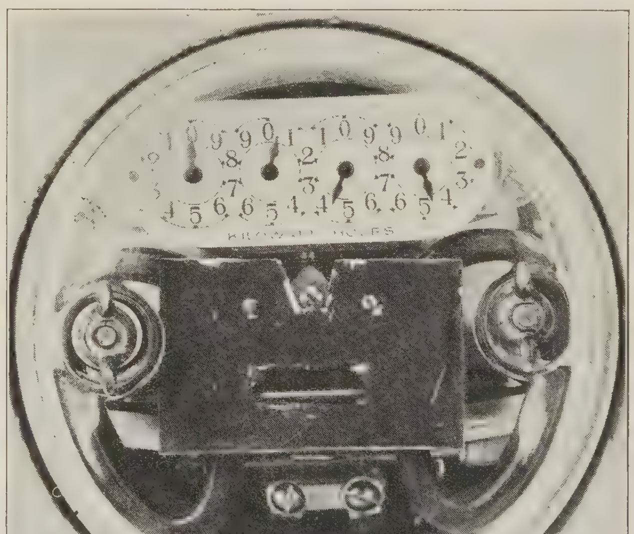


Fig. 3—Watthour Meter With Stroboscopic Lines on Disk

The motor is of the high-speed, high-torque type so that it will follow the regulator quickly. This feature would cause the regulator to hunt if it were not properly damped. A magneto with a straight line speed—voltage curve is used and direct connected to the motor by means of a special coupling. This magneto must have annular ball bearings and a very well made commutator.

The light-impulse commutator mounted on the non-

flexible end of the coupling has eight sections equally spaced consisting of four metal bars and four insulated sections. The metal bars are held in place by shrink rings which short-circuit them, forming a simple flashing commutator. The brush support is a ring section with one permanent and one adjustable brush. The adjustable brush may be adjusted to the proper "cut-off" or "light-on" position to produce a clear vision of the lines. At slow speed this adjustment is proportional to the ratio of width of space to the width of line on the disk. At high speed such adjustment is not required. It may, therefore, be set for the low-speed point and fixed, namely at 5 per cent of full load as this is about the lowest point at which the stroboscopic effect has been found satisfactory.

A special lamp is connected with a battery or rectifier unit in series with the commutator, so that for each revolution of the magneto, the light is on and off four times. This means that the lamp will have to flicker at a maximum frequency of $300 \times 25 = 7500$ cycles per minute. This is too fast for standard lamps, and a high-speed lamp such as used in aero signaling was developed in miniature for this work. It is necessary to have a cooling medium and hydrogen gas is used. It was found that 15,000 light periods per minute could be recognized by means of the stroboscope when using this lamp. The possibility of air leaking into the lamp makes it necessary to enclose the lamp completely and to vent the housing to provide for explosion. The explosions are very powerful and danger exists unless properly guarded lamps are used. The current consumed by the lamp is above normal, because the gas absorbs a large portion of the heat at a high rate.

A flood-light may be used for gang or group testing, either for one bench or for several. In fact, the overhead lighting in the laboratory may be changed to operate with this system. Where the room has exceptionally good daylight, it may be best to use a small hand lamp with a focus beam; or the operator may use dark glasses. Dark glasses seem to protect the eyes, preventing eye fatigue.

Balance Indicator

The balance indicator acts as a check on the regulator when calibrating, and as an error indicator when checking. In the laboratory it should be mounted directly above the tester's position at the test bench. It is similar to an indicating polyphase wattmeter except that one element is a d-c. voltmeter of the d'Arsonval type and is connected to buck the watt element mechanically. Both elements have a uniform scale and, as a result, the pointer indicates the difference which may be calibrated in watts or in per cent at one load. The author is devising an instrument which will read per cent for all loads. The connections for the balance indicator are shown in Figs. 1 and 2.

The Automatic Regulator

In making tests, no means is provided for keeping the watthour meter load absolutely constant. Therefore, in calibrating, the speed of the stroboscope motor must be varied as the watt load changes and for great accuracy this must be done by an automatic regulator. This regulator keeps the speed proportional to the load. As already mentioned the a-c. measuring element of the regulator is connected to measure the same load as that which the watthour meter measures, and the d-c. voltmeter element is connected to the magneto. These two elements are mechanically connected in opposition. The measuring elements, by means of contacts and the reversing motor, control the series resistor of the commutator motor. The contacts are of the standard three-point type such as are used in graphic meters.

As the wattmeter element is of the Kelvin-balance type, it has a straight-line scale of watt values. This means that there must be a buck-balance with a similar straight-line scale. The standard d-c. voltmeter of the d'Arsonval type may therefore be used for a buck balance. With these two elements mechanically connected in opposition, they will find a point of balance over their entire range. This means that the speed must be proportional to the watts; otherwise the balance will close its contacts, causing the control motor to adjust the series resistor until a balancing speed is obtained through the voltmeter element. This part of the scheme is the heart of the device. Taps for voltage, a range for various current capacities, and a changeover switch on the voltmeter element for various makes of meters should be provided.

When a precision wattmeter is used, the torsion head should be left intact, so that it may be checked with a potentiometer, the calibration of the device being thus established from this point. The torsion spring will have practically no effect, as the balance operates at zero torque, and with practically no movement. On the other hand the torsion head may be set to balance part of the meter torque and thus eliminate the necessity for some of the switches and taps.

The voltmeter element should be of the finest workmanship; also it should be connected to the wattmeter through suitable mechanical linkage and the entire balance must be properly damped.

This part of the device should be built so that it may be located near a standardizing bench, thereby facilitating a check test on the outfit.

Operation

The general diagram of connections, as shown in Fig. 2 gives an idea of the electrical connections used for the laboratory set. A source of alternating current is required for loading the watthour meter, the Kelvin balance, and the wattmeter element of the per cent indicator. A small source of direct-current is required

for the light. This may be a battery or rectified alternating current with a wave filter in the circuit.

Several load switches are required to cover the testing range. The major switches cover full load, light load and 50 per cent power factor.

To make a check or "as found" test throw the regulator switch to the check position which cuts out the regulator and cuts in the hand control. Then adjust the set until the lines stop moving and read the per cent indicator.

In calibrating, the power is supplied to the load deflecting the watthour meter, Kelvin balance, and per cent meter. This upsets the balance, starts the watthour meter, and gives an indication on the per cent indicator. The Kelvin balance then closes its contacts which control the motor on the rheostat. This decreases the resistance in the commutator-motor circuit until this motor reaches a speed at which the voltage generated by the magneto produces a torque on the voltmeter element that bucks the Kelvin balance and equals the torque developed by the watts in the meter circuit. The contacts then open and regulate the speed of the commutator motor by increasing or decreasing the series resistor.

The speed of the commutator is the same as that of the motor, so that the light is impulsed at a proportional speed. This speed depends upon the number of segments on the commutator. When the frequency of the light impulses is the same as that of the movement of the lines on the watthour meter disk, or the disk line movement is synchronized with the light, the lines will appear to stand stationary, which is the well-known stroboscopic effect. If they are not synchronized, there will be progression for high speed on the meter or retrogression for low speed on the meter, indicating that the meter is out of step or calibration. In some of the standard meters, moving the adjustment screw in the direction of the line motion will correct the error.

While this action has been taking place, the balance meter has been indicating the difference in calibration, as it functions the same as does the regulator. The two elements are bucking and as a result, when speed is proportional to watts, this instrument should read zero or 100 per cent. When the regulator is in use for calibrating, the balance indicator is simply a check on the regulator; but when the hand control is used for checking, this indication reads watts error plus or minus, slow or fast.

At this point it may be well to bring out the fact that the disk markings may appear stationary at harmonic values of speed, but the image is very poor at such values. At the calibration values the image is very sharp and clear. Also, noting the action of the per cent indicator and the range of calibration of the watthour meter will prevent mistakes.

After the above mentioned operations have been taken care of, note the per cent indicator to see if the regulator is functioning properly. Then observe the line movement and adjust the tested meter until the lines stop. Then test for the other load and power factor by simply throwing the proper switch, as the regulator will take care of the change.

The meter under test may be connected after the set is started if quick-connection test blocks are used, as the regulator will take care of the system when the test meter is out of the circuit by stopping the commutator motor, exactly as it would for a no-load condition. This means that no time is lost while changing meters. Because of a possible short circuit at the lead ends, this procedure is not advisable if leads are used to connect the test meter.

Accuracy of Test

As personal errors of switching are eliminated in this laboratory set the accuracy will be materially improved. A second point is that a precision wattmeter may be used, if desired, giving maximum accuracy while calibrating. Observation of the motion of the lines is made through a cylinder type of lens which apparently

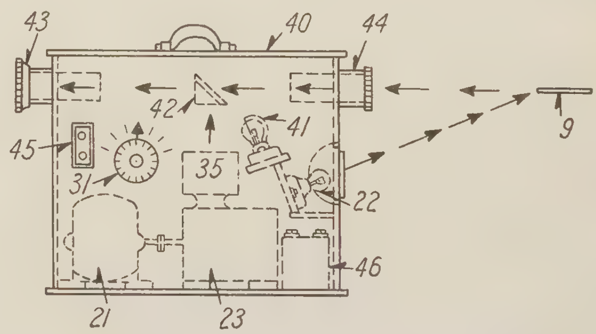


Fig. 4—Schematic Drawing of Portable Stroboscopic Watthour Meter Checker

speeds up the motion in case of slow speed. The author has tried several types, and this cylinder lens gives the best results, although a telescope with cross hairs will give minute measurements.

It has been found by test that progression of one line one division in 30 sec. is quite perceptible with the unaided eye. Therefore the error which may be discerned equals a movement of 1/30 division in one second.

Full load on the meter used is 500 watts and the disk constant is ⅓. Therefore at 500 watts the disk will revolve at the following speed:

$$n = \frac{500}{3600} \div 1/3 = 0.4167 \text{ rev. per sec.}$$

As there were 300 equal divisions on the disk the number of divisions per second is $0.4167 \times 300 = 125$ divisions per sec. But the error which can be read equals 1/30 division per second. Expressed in per cent this is $1/30 \div 125 \times 100 = 0.026$ per cent. Translated into watthours at full load this equals:

$$500 \times 0.026 \div 100 = 0.13 \text{ watt-hr.}$$

The same percentage of visibility holds true through the entire range, as both light-interval speed and disk speed reduce in the same ratio, so that progression is a result of per cent difference and not of disk speed. As mentioned before the stroboscopic effect is not satisfactory at less than about 5 per cent of full load speed on this meter or about 375 light cycles per minute.

With a cylindrical lens this factor may be magnified about ten times due to the radius of the lens and therefore an error of 0.0026 per cent may be detected.

This entire system depends upon the accuracy of the regulator. A Kelvin-balance instrument, or moving-coil type will give a minimum error and the total of the entire system has a far better accuracy than can be obtained by present methods.

Portable Outfit

By eliminating the regulator and reducing the size a portable checker may be made. This would consist of the lamp, per cent indicator, commutator, motor and magneto as previously described. The motor will be hand-regulated by a rheostat at the side of the case.

In the portable form an optical system will be introduced in which the lines on the disk of the test meter will be reflected on a ground-glass scale on which the per cent scale is marked. This will make it easy for the operator to watch the lines and to read the scale while he adjusts the speed of the commutator motor with the hand rheostat.

This checker should be about the size of a portable watthour meter and as light in weight. Proper provision should be made for connections to the circuit and a small rectifier and filter should be contained in the outfit for the lamp supply. Fig. 1 shows the wiring diagram and Fig. 4 shows the schematic layout of this portable set.

Conclusions

The device described in this paper is now in the experimental stage. One of the devices has been in operation for about one year with constantly increasing accuracy and elimination of troubles as experience is gained.

The device has been successfully worked over a range of 4 per cent to 200 per cent of load without eye strain. Work may be done with or without dark glasses, as required by the intensity of other light present.

Consistent average accuracy above the present-day methods has been obtained. Experience with the device indicates that a very gratifying reduction in cost of calibrating and testing watthour meters should be realized through its use.

USEFULNESS OF VACUA

Strive as they may, scientists have been unable to attain a vacuum wherein a cubic inch includes fewer molecules than there are people in the world. Even so they have succeeded in removing 99.99,999,999 per cent of the gas. In other words, only one of every 10,000,000,000 molecules remains; yet there are 40,000,000,000 molecules in every cubic inch; the population of the earth is estimated at less than 2,000,000,000.

Across the broad girth of America, from New York to San Francisco, a four days' journey by train, thirty hours by swiftest airplane, imagine a great belt of fine sand a thousand feet, or nearly a fifth of a mile, in width and ten feet deep. Its length, from coast to coast, would be more than 2500 miles. Then imagine it suddenly reduced to a line, so slender as to be almost invisible, just two grains broad and one grain deep.

That is a graphic illustration of how completely a modern Coolidge x-ray tube is exhausted of air by the high efficiency Langmuir condensation pump in the research laboratory of the General Electric Company. The great beach with its millions of millions of grains of sand is symbolic of the cubic inch of air at atmospheric pressure, if each of its molecules were enlarged to the size of a grain of sand one one-hundredth of an inch in diameter, and the line two grains broad and one grain deep represents the almost complete vacuum obtainable with the Langmuir pump. No vacuum known to science is absolutely complete.

The swiftness with which the air is drawn out is equally marvelous. If, from a vessel holding a quart, there were removed a million molecules a second, it would take 750,000,000 years to remove practically all of its air; but the Langmuir pump accomplishes this in just two seconds.

It can hardly be said of a vacuum, as we know it, that "There's nothing in it." Materially, there are countless thousands of molecules in the highest vacuum attained; there is also endless interest and utility. In fact, the American public is paying more than a million dollars a week for glass-contained vacua.

Ability to create even partial vacua in enclosed spaces has been of great use. It has made possible suction pumps, thermometers, incandescent electric lamps and many improved physical and chemical processes, and has increased the efficiency of steam engines and turbines.

At night we see largely by the aid of vacuum lamps. By means of other vacuum lamps (x-ray tubes) we can also see through opaque bodies. Our transcontinental wired telephony is possible through vacuum tubes, which, in various forms, also permit our radio broadcasting and radio reception from the most remote stations. One of the latest achievements of science, the transmission of photographs by wire or wireless, incorporates still another vacuum tube, the photoelectric cell.

The workman who keeps his drink hot or cold in a thermos bottle is indebted to Sir James Dewar's application of the vacuum, but the scientist is still more indebted to it. Our steampower plants, including turbines, also owe their success to vacua.—*Research Narratives.*

A-C. Network Relay Characteristics

BY D. K. BLAKE[1]

Associate, A. I. E. E.

Synopsis.*—This paper discusses the required characteristics of relays for use with a low-voltage automatic network circuit breaker. The relay performs the two functions of tripping and reclosing the circuit breaker. The characteristic required for each function is discussed.*

The major part of the paper is given to a discussion of the reclosing function because of the danger of "pumping" caused by cable charging currents and various combinations of induction regulators and transformer connections.

Emphasis is placed on the suitability of relays consisting of watthour meter characteristics, construction and adjustments, involving only a different current coil and the replacement of the recording mechanism by standard relay contacts.

* * * * *

Introduction

ABOUT eleven large central station companies have recently installed, or are now installing, low-voltage a-c. networks in areas of high load-densities. With the exception of three companies, all of the networks utilize a low-voltage automatic circuit breaker connected in the transformer secondaries. The major elements of these systems are shown schematically in Fig. 1. It is the purpose of this paper to discuss the functions and required characteristics of the relays for controlling the operation of the breakers.

Functions of the Network Relay

Broadly, the relay performs the two functions of tripping on reversals of energy and reclosing when the incoming circuit is energized.

Tripping function. The relay must trip the breaker on short-circuit currents in the reverse direction. It must also trip on the transformer exciting current in the reverse direction in order to permit the disconnecting of a feeder and its transformers from the network by opening the feeder breaker at the substation. The characteristic of the relay must be such that the addition of any amount of cable charging current to the exciting current will not prevent tripping in the reverse direction.

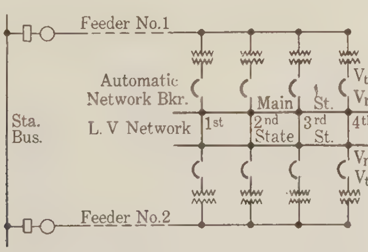


Fig. 1—Typical Low-Voltage, A-C. Network Utilizing Automatic, A-C. Network Circuit Breakers

The vector diagram in Fig. 2 indicates a suitable characteristic for the tripping function. The short-circuit current will probably lag at a maximum angle when a short circuit occurs at the high-voltage terminals of the transformer. This angle is 84.3 deg. with a transformer having a one per cent resistance and 10 per cent reactance drop. If the parallel lines $T\,T$ are perpendicular or slant in the leading direction as shown, it is obvious that if the relay will operate on the transformer exciting current it will also operate on any amount of charging current which may be added. The watthour meter has a similar characteristic.

The tripping function then requires no new untried

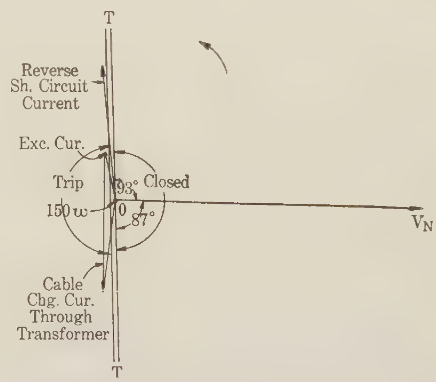


Fig. 2—Vector Diagram of Tripping Characteristics

devices since it is possible to utilize watthour meter parts and construction to form a simple induction type reverse power relay. The connection shown in Fig. 3 is suitable, being similar to the connection for measuring power. The current transformer and current coil of the relay are designed together to operate over the entire range of reverse current. This range may be from 1.5 amperes to 15,000 amperes. The current transformer has a relatively small number of turns to give sufficient secondary current for relay operation on exciting current and a small amount of iron to limit, by saturation, the secondary current to a safe value for the relay current coil. The time-current characteristics should be such as to require, under short-circuit conditions, not longer than ½ sec. A much shorter time, such as ¼ sec., is preferable.

Reclosing function. The network breaker should reclose only when the incoming transformer voltage is of the proper value and phase relation to cause the transformer to take its share of the network load. This requirement does not permit connecting the

1. Central Station Engineering Dept., General Electric Co., Schenectady, N. Y.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

closing circuit direct to the transformer secondary because after opening the circuit breaker at the substation it would be possible for some network breakers of the particular feeder to open and reclose again before all the breakers opened. The result would probably be a "see-saw" operation of opening and closing. Induction regulators may also cause low voltage on a feeder by being in the buck position when the feeder is energized. Other factors will be discussed later that may cause improper voltage relations. It is obvious, therefore, that the relay should measure the voltage across the open breaker contacts and complete the closing circuit only when the voltage difference is of a certain value in the proper direction.

The voltage difference may be measured by a separate relay, by an extra winding on the reverse power relay, or by the current coil of the reverse power relay. This paper will treat of the latter arrangement (Fig. 4) and the use of a separate phasing relay where the connection shown in Fig. 4 would not be suitable.[2]

The circuit of Fig. 4 is similar to Fig. 3 with the ad-

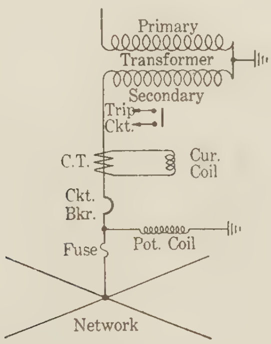


Fig. 3—Relay Connection Diagram For Tripping Function

dition of an extra relay contact for the closing circuit and the connection of the current coil across the circuit breaker contacts. When the circuit breaker is closed the relay acts as an ordinary reverse power relay and when the circuit breaker is open the relay acts as a voltage direction relay. The tungsten lamp has an approximate resistance of 140 ohms cold and 1400 ohms hot. It therefore prevents short circuiting the relay coil when the breaker is closed and protects the relay coil when the voltage across the open breaker is high, such as 115 to 230 volts.

The current through the relay coil does not increase directly with the voltage because the resistance of the lamp also increases with the voltage. The high value of the lamp resistance limits the total possible current through the relay coil to a value appreciably below the value of the secondary current corresponding to transformer exciting current. It is obvious, therefore, that the time required for operation is appreciably longer. The impedance of the current transformer at current values passed through the lamp is much greater than the impedance of the relay coil. Thus its connection in parallel does not interfere with the relay operation.

The potential coil is connected on the network side to keep the relay energized when the transformer is de-energized. This arrangement permits a strong

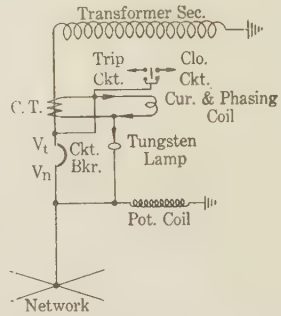


Fig. 4—Relay Connection Diagram For Both Tripping and Reclosing Function

torque in the tripping direction with the breaker open insuring against the breaker reclosing as soon as the transformer is energized. The relay must close the closing circuit by a spring when the network, and consequently the potential coil of the relay, is energized. It is also desirable, but not necessary, to have the relay protect against reclosing when phases are crossed or reversed by workmen during installation or repair work. Obviously, such protection would not be obtained if the potential coil is on the transformer side, because it is reversed with the transformer voltage.

The current coil of the relay has an impedance of less than two ohms. The resistance of the tungsten lamp cold or hot determines that the current through

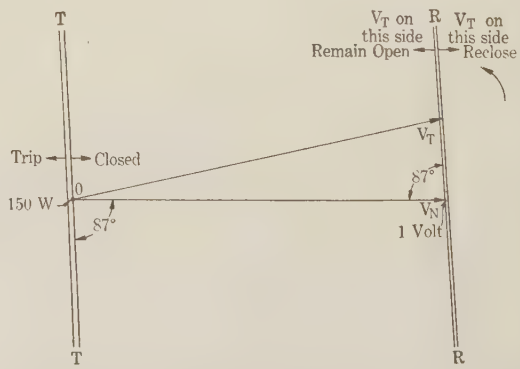


Fig. 5—Vector Diagram For Both Tripping and Reclosing Function

the relay coil is practically in phase with the voltage across the breaker, enabling the relay to operate according to the direction of this voltage as it does according to the direction of the line current. The lines RR similar to the lines TT in Fig. 2, therefore, may be drawn through the end of vector Vn as indicated in Fig. 5. The direction and magnitude of the voltage

2. See companion papers by Bullard and Parsons for treatment of relay using an extra phasing winding in the relay.

across the switch is represented by a vector drawn from $V\,n$ as its origin to $V\,t$ as its terminus. Therefore $V\,t$ must go beyond $R\,R$ in order to reclose the breaker. This characteristic obviously protects against reclosing on cross or reverse phases since the voltages would lead or lag the network voltage 120 deg. or 180 deg.

Reclosing where no feeder regulators are used. Where no feeder regulators are used, the difference in voltage that usually exists across the network breaker is that caused by the impedance drop from the substation to the network. The direction of this voltage depends on the impedance angle and the power factor. At unity power-factor it leads the network voltage at an angle equal to the impedance angle. For power factor less than unity, this impedance voltage lags its unity power-factor position by the same angle that the current lags the network voltage. Therefore, for lagging power-factors, it is always on the right hand side of the lines $R\,R$ of Fig. 5. This impedance voltage will always cause the incoming transformer to carry its share of the load.

It is necessary to design the relay with a reclosing

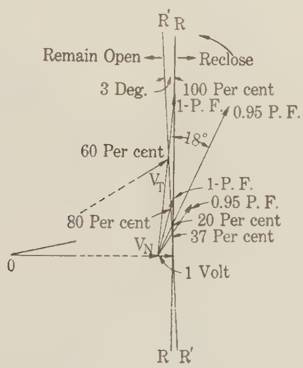


Fig. 6—Vector Diagram Showing Transformer Impedance Voltages Used For The Reclosing Function

characteristic so that it will be certain to close in on the impedance voltage which does not exceed the impedance voltage corresponding to full load current. It is desirable to have the breaker reclose at an impedance voltage corresponding to a value considerably below full load current. Otherwise, it would not be possible to switch in a new transformer or circuit at times other than full load.

The total impedance voltage across the breaker is the resultant of the primary feeder, transformer, and secondary main impedance voltages. It is advisable to use only the transformer impedance voltage in the relay design because it is possible for one breaker to reclose ahead of another, leaving only the transformer impedance voltage for the remaining breaker in cases where two or more transformers are located at the same point or close together. In Fig. 6 is shown the impedance voltage of transformers radiating from the end of $V\,n$. The long vector corresponds to full-load impedance voltage of a high reactance (10 per cent) transformer and the short vector a low reactance transformer. The resistance component of each vector is the same. Two positions are indicated for each vector corresponding to unity power factor and 0.95 power factor.

If the relay is designed with the line $R\,R$ perpendicular and adjusted to close on a component of one volt in phase with the network voltage, it is obvious that approximately full load current at unity power factor is required on the adjacent transformer, either high or low reactance, to give this one volt. If the power factor lags to 0.95, the conditions are considerably improved, the high-reactance transformer closing in on 20 per cent load and the low reactance on 37 per cent load. If the relay is adjusted for ½ volt instead of one volt, these values are reduced to ½ for either the unity or 0.95 power factor position. Now suppose the line $R\,R$ is advanced about three deg. to the position $R'\,R'$. Then the unity power factor condition is considerably improved, being reduced from 100 per cent load to 60 per cent for the high-reactance transformer and to 80 per cent for the low-reactance transformer. The low power factor condition is not changed very much. Notice that the high-reactance transformer is much better for this operation than the low reactance. The line $R\,R$ should be much further advanced if closing in on leading currents is required.

It is probable that an adjustment of about one volt will be satisfactory because most network transformers have high reactance and the power factor is not likely to be higher than 0.95. It seems, therefore, that the relay should have a range of adjustment from ½ to two volts in phase with the network voltage. This may be accomplished by using a device similar to the usual light load adjustment supplied with standard watthour-meters. This adjusting device gives a torque that opposes the closing torque exerted by a spring.

It has been previously explained that the relay will operate on cable charging current in the reverse direction. This charging current does not usually become appreciable until high voltage such as 13,200 volts is used for the primary feeder. Suppose a 13,200-volt feeder has only two transformers feeding the network and that the substation feeder breaker is opened. Then the two relays go to the tripping position. No. 2 breaker of Fig. 7 trips all right but for some reason No. 1 breaker does not trip. The cable may have a charging current of one ampere per phase per mi. and may be five mi. long, giving a total charging current I_c of five amperes or $5 \times 13.2 \times 1.73 = 96.8$ kv-a., which is approximately ⅓ load on a bank of 300 kv-a. This charging current flowing through the transformer causes a voltage to appear across the open breaker No. 2. This voltage $V\,n$–$V\,t$ leads the charging current by an angle equal to the impedance angle of the transformer and is about 84.3 deg. for a 10 per cent reactance transformer. Obviously, breaker No. 2 will reclose but will trip again because of the reverse current. It will

periodically reclose and trip (called "pumping") as long as breaker No. 1 remains closed or until something happens to breaker No. 2. If the closing circuit of the breaker does not require very much current, voltage fluctuations are not likely to be noticed by the consumers. If the relays are designed so that it takes a much longer time for reclosing than for tripping, it is not possible for a "see-saw" action to take place by some breakers opening before the others.

Trouble from this pumping may be avoided in several

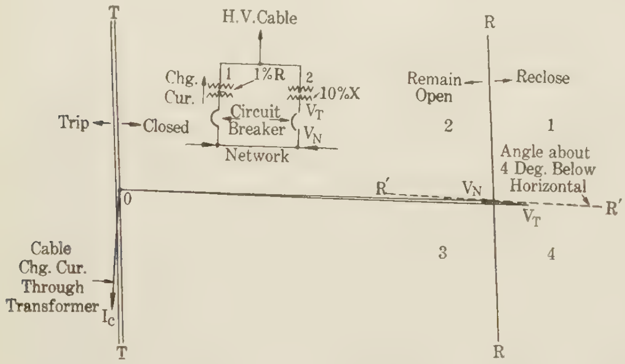


FIG. 7—VECTOR DIAGRAM SHOWING HOW REVERSE CABLE CHARGING CURRENT MAY CAUSE "PUMPING"

ways. The substation operator could stop the pumping by simply reclosing the feeder circuit breaker, for a voltmeter would indicate back feed which means that one or more switches failed to open. Two or three operations of the substation breaker might clear the breaker which stuck. If not, an inspection would be necessary to locate the faulty breaker. The exciting current of the other transformers on the feeder will greatly reduce the charging current flowing through transformer No. 1. Suppose the total transformer capacity on the feeder is 5000 kv-a.; then the exciting current may be approximately two per cent, or 100 kv-a. more than enough to overcome the charging current. If the transformer exciting current is lower than the charging current, it could be increased by connecting a reactor to the feeder at the substation.

The relay characteristics may be modified by changing the design of the relay itself or by adding a separate relay to prevent reclosing on voltages that lag the network voltage more than three deg. to five deg. All the phases of a three-phase system are affected approximately the same by the charging current; therefore it is feasible to employ only one extra relay to prevent reclosing on voltages in the lagging direction. The relay would be identical in construction to the usual relay except that the tripping contact is omitted and a different set of coils designed so as to give the characteristic shown at $R' R'$ in Fig. 7. The phasing coil is connected across the contacts of one pole of the breaker and closes its contacts on any voltage vector in sectors 1 and 2, Fig. 7. The contact of this relay is connected in series with the closing circuit of the standard relay which closes its closing contacts when voltages occur in the sectors 1 and 4. The closing circuit, therefore, is energized only when voltage vectors occur in sector No. 1. The connections of the two relays across one pole of the breaker and the resulting characteristics are shown in Fig. 8.

Case of three single-phase regulators. When the feeder voltage is regulated by individual induction regulators the voltage existing across the contacts of the breakers of the incoming feeder may not be that due to the impedance voltage but may be modified in direction and magnitude by the position of the regulators. The simplest case involving regulators is the three-phase, four-wire feeder regulated by three Y-connected, single-phase regulators and supplying Y-Y connected transformers. In this case the regulators always boost or buck the voltage in phase with the substation voltage. Therefore, with this combination, the incoming transformer voltage is always in phase with the substation voltage. The cable charging current has a negligible effect on the receiving voltage because of the low resistance and reactance of the cable. The substation voltage can lag the network voltage only when the load power-factor angle at the network is greater than the resulting impedance angle of the primary feeder, transformers and network mains. Suppose this resulting impedance angle is 60 deg.; then the power factor must be lower than 50 per cent in order that the substation voltage may lag the network voltage. If the impedance

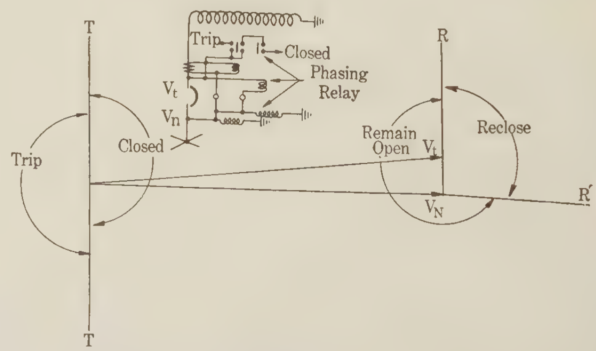


FIG. 8—RELAY CHARACTERISTIC THAT WILL PREVENT "PUMPING"

angle is 30 deg. the power factor must be lower than 86.6 per cent. As long, therefore, as the combination of impedance angle and load power factor is such as to keep the substation bus voltage in the leading position as shown in Fig. 5, the regulators cannot set up a condition that will cause pumping. If the regulator bucks the voltage $V\,t$, Fig. 5, the breaker cannot reclose. If they boost the voltage $V\,t$, the voltage difference across the breaker cannot cause pumping because the lag of the current set up cannot be over 90 deg. and will be on the closing side of the lines $T\,T$.

If the phase angle and power factor are low enough to cause the substation voltage to pass to the lagging

position, it is possible for the regulator to buck the voltage $V\,t$ shown in Fig. 9 to $V'\,t$ which will cause pumping by setting up a circulating current. In Fig. 9, I_n is the load current the feeder would take if the regulators were not present, I_c the circulating current set up by the regulator running towards the buck position, and I_r the resultant current through the relay which trips the breaker. $V'\,t$ is just at the point where it will close the breaker, thereby causing pumping. While this condition is theoretically possible, it is believed that practical systems will have an impedance

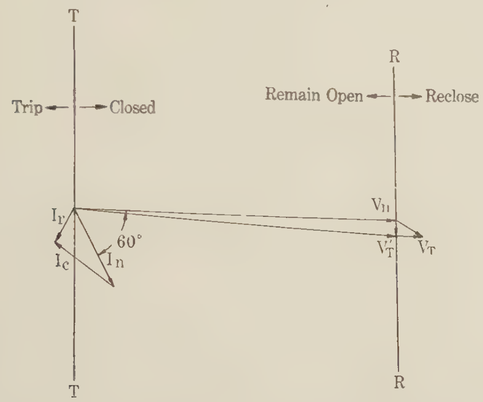


Fig. 9—Vector Diagram Showing How "Pumping" may be Caused by Single-Phase Regulators in Each Phase

angle and power factor sufficiently high to avoid substation voltages being in the lagging direction. Where this is not true it will be necessary to advance the line *R R*, Fig. 9, at an angle from the vertical equal to the resulting impedance angle of the loop circuit formed by the incoming feeder, the network and one or more feeders already supplying the network. This characteristic prevents the breaker from reclosing on voltage differences that have an angular position such as to set up a circulating current that will appear on the tripping side of the line *T T*. It is not certain, however, that the impedance angle of the loop will remain constant with a varying number of feeders in service and as the system continues to grow. These facts would require that the relay have an adjustable feature to advance or retard the line *R R*, Fig. 9, which is not an easy thing to accomplish without seriously complicating the relay.

As previously explained, the normal operation of the regulators would cause no trouble. It is only in the rare condition where a regulator runs to full buck by some means that trouble is caused. An inspection of Fig. 9 will show that the usual difference in regulator positions due to contact-making voltmeter adjustments will cause no trouble because the small circulating current set up by the regulators would not be sufficient to subtract from the load current.

Use of polyphase regulators. If the polyphase regulators are used, it is possible for the regulators to cause a voltage difference across the open breaker of the incoming feeder that will lag the network voltage and cause pumping with the relay characteristic shown in Fig. 5. An inspection of Fig. 10 will show how this is possible. It is more convenient in this case to draw the substation voltage V_s as the reference vector. The polyphase regulator voltage is a constant value and changes the feeder voltage by moving from x to y along a circular path. The diagram indicates that one regulator is at the neutral position V_n and the other is appreciably advanced to the boost position V_t. The voltage across the open breaker is $V\,n$–$V\,t$ and sets up the circulating current $I\,c$. This would cause pumping at no load or at light loads.

The minimum circulating current required to cause pumping at a given load is determined by the power factor of the load current. At unity power factor the minimum is approximately equal to the load current; at 80 per cent power factor the minimum is approximately 80 per cent of the load current. This minimum value must have a phase relation opposite the network voltage. As it varies from this position its numerical value is increased in inverse proportion to the cosine of the angle. These statements are made assuming that the line *T T* in the diagram is perpendicular but since it is advanced about three deg. the values are not exact. If the total impedance of the loop is 20 per cent it will require a voltage difference of about four per cent to equal the load current at 20 per cent load. It is probable that pumping would occur at such loads since with polyphase regulators it is possible for the contact-making voltmeter to cause a phase displacement of four per cent within the limits of its adjustment. As the impedance of the loop increases or the load increases, this danger is eliminated. It would then

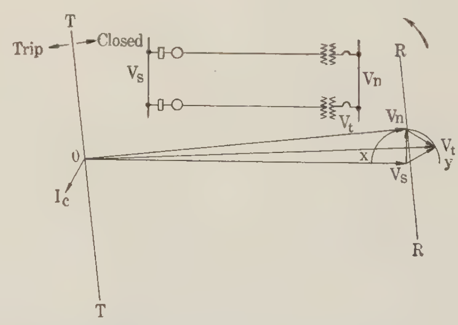


Fig. 10—Vector Diagram Showing How Polyphase Regulators May Cause "Pumping"

require some fault in the regulator automatic control equipment to cause pumping.

Hand control of the regulators would be likely to give trouble from pumping. The mechanical interconnection of the regulators would eliminate pumping caused by regulator displacement. The relay characteristic may be modified so that the switch cannot reclose on voltage differences that will set up a circulating current on the tripping side of the line *T T* in Fig. 5. The relay characteristic shown in Fig. 8 is suitable. Only one phasing relay is necessary because the regulator affects

all phases alike. The breaker cannot close in on a voltage difference that is lagging the network voltage more than three deg. The current lagging this voltage will not exceed 84 deg. on modern systems. Therefore, no phase angle adjustment is necessary.

Use of two single-phase regulators. When two single-phase regulators are used in open-delta connection it is possible for one of the phase voltages to be displaced by the regulators to either the lag or lead position. A reference to Fig. 11 will explain how this takes place. The equilateral triangle $A\ B\ C$ represents the bus volt-

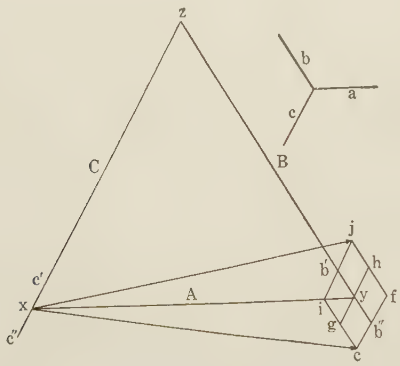


Fig. 11—Vector Diagram Showing how two Single-Phase Regulators Open Delta-Connected may Cause "Pumping"

age and also the line voltage when the regulators are in the neutral position. The normal operation of the regulators increases or decreases the voltage triangle symmetrically. No phase displacement occurs. The voltage range of the regulator in C phase is shown as $c' - x - c''$ and in B phase as $b' - y - b''$. Therefore, phases B and C cannot be displaced by the regulators. The only phase affected is A phase.

Suppose the line voltage is impressed on a transformer bank with the high voltage connected delta and the secondary connected Y with the neutral grounded; then the secondary voltages a, b, c correspond in phase with the primary voltages A, B, C. Phases B and C are not displaced by the regulators. Suppose regulator C is in the neutral position and regulator B is run to the full buck position at b''; then voltage A or a is shifted to the lagging direction. Now when regulator C is operated from buck to boost (c' to c'') the end of vector a travels from e to n. When regulator B is in the neutral position and regulator c is varied from c' to c'', the voltage vector moves from g to h. The same thing is true with B regulator in the buck position where a varies from i to j. Obviously, the regulators can be made to cause the secondary voltage a to occur at any point in the diamond shaped area e, t, j, i. The normal operation of the regulators bucks or boosts the secondary voltage in phase with it along the path $i - y - f$.

A three-pole circuit breaker is equipped with three single-pole relays having their tripping contacts connected in parallel and the closing contacts connected in series. If the voltage is low on one phase the breaker cannot reclose. The circuit breaker, therefore, can be reclosed by the regulators only in the diamond shaped area $y - b'' - f - h$. This is because all the other small areas require one of the regulators to be in the buck position. The foregoing discussion refers to the no-load condition. The impedance voltage is added vectorially to the regulated voltage.

The normal operation of these regulators with the usual possible two per cent difference is not likely to give enough circulating current to cause pumping. In this case a change in position of the regulators causes a more direct change on the voltage applied to the contact-making voltmeter than does the polyphase regulator which depends on the rotation of a voltage vector to produce an effect on the voltmeter. If one regulator is one per cent high and the other one per cent low, the result is a 1.73 per cent voltage to produce a circulating current which cannot cause any trouble unless the load is around 10 per cent and at a very low power factor. Therefore some trouble must develop in the regulator control circuit to cause positions that will produce pumping. The regulators being in the same circuit makes it very convenient to interconnect them mechanically so that they cannot cause a phase displacement. This causes all three phases to be regulated together but the loads of modern network systems are so well balanced that separate phase regulation is not essential.

The characteristics indicated in Fig. 8 may also be used to prevent reclosing on transformer voltages that are in the lagging direction. This characteristic is necessary only on the one phase affected by the regulators. The other two phases can use the characteristic

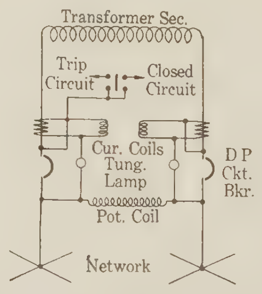
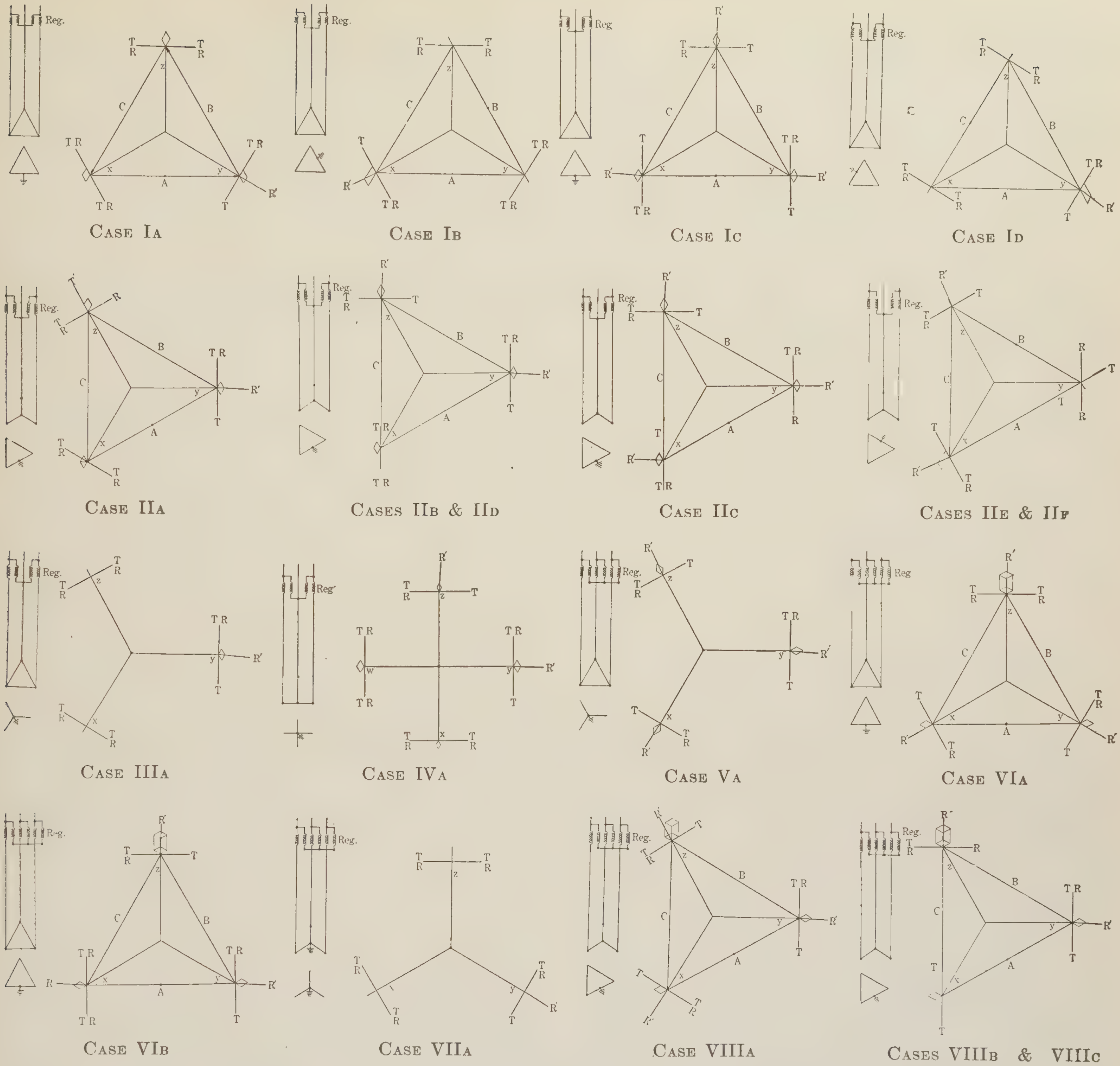


Fig. 12—Connections of one Two-Circuit Relay for Double-Pole Breakers

indicated in Fig. 5. It is also possible to utilize a directional voltage relay with a winding on each side of the regulators that will close an alarm circuit when the regulators cause a voltage displacement in the lagging direction. The operator could readjust the regulators by hand control until the alarm circuit is opened. The pumping which might occur in the meantime would do no particular harm.

One large eastern company is installing a network utilizing two single-phase, 13,200-volt regulators in open-delta and Scott-connected transformers supplying a two-phase, five-wire network. Both of the phases may be displaced by the regulators. They intend to



FIGS. Ia TO VIIIc TRANSFORMER AND REGULATOR CONNECTIONS

Case	No. of Single-Phase Regulators	Transformer Connections	Secondary Grounded on—	Number and Type of Relays
Ia	2	Δ–Δ	Phase A	3 Standard 1-Circuit 1 Phasing
Ib	2	Δ–Δ	Phase B	3 Standard 1-Circuit 1 Phasing
Ic	2	Δ–Δ	Phase A	1 Standard 1-Circuit 2 Phasing relays (1 with 2-circuit) 1 Standard 1-Circuit on Phase A
Id	2	Δ–Δ	Phase C	1 Standard 1-Circuit 1 Phasing 1 Standard 2-Circuit on Phase C
IIa	2	Y–Δ	Phase A	3 Standard 1-Circuit 2 Phasing
IIb	2	Y–Δ	Phase A	1 Standard 1-Circuit 2 Special 1-Circuit 2 Phasing
IIc	2	Y–Δ	Phase A	1 Special 2-Circuit 1 Standard 1-Circuit 1 Phasing
IId	2	Y–Δ	Phase A	3 Standard 1-Circuit
IIe	2	Y–Δ	Phase B	1 Standard 1-Circuit 2 Special 1-Circuit 3 Phasing
IIf	2	Y–Δ	Phase B	1 Special 2-Circuit 1 Special 1-Circuit 1 Phasing
IIIa	2	Δ–Y	Neutral	3 Standard 1-Circuit 1 Phasing
IVa	2	Scott	Neutral	2 Standard 2-Circuit 2 Phasing
Va	3	Δ–Y	Neutral	3 Standard 1-Circuit 3 Phasing
VIa	3	Δ–Δ	Phase A	3 Standard 1-Circuit 3 Phasing
VIb	3	Δ–Δ	Phase A	1 Standard 1-Circuit 1 Standard 2-Circuit 1 1-Circuit Phasing 1 2-Circuit Phasing
VIIa	3	Y–Y	Neutral	3 Standard 1-Circuit 1 Phasing
VIIIa	3	Y–Δ	Phase A	3 Standard 1-Circuit 3 Phasing
VIIIb	3	Y–Δ	Phase A	1 Standard 1-Circuit 2 Special 1-Circuit 3 Phasing
VIIIc	3	Y–Δ	Phase A	3 Standard 1-Circuit

mechanically interconnect the regulators to avoid any possibility of phase displacement. The initial installation consists of a double-pole circuit breaker for each transformer. A single relay with two current circuits is used with each circuit breaker. The connections are shown in Fig. 12.

Other combinations of regulators and transformer connections. There are other combinations of regulators and transformer connections possible. The foregoing discussion covers the cases that are now operating or being installed. Appendix A covers an analysis made of combinations likely to be considered. The results are in tabular form because a treatment of each case would require too much space. Enough is included to enable anyone interested in a particular combination to check the factors affecting the relay characteristics.

TABLE I

ANALYSIS OF NETWORK RELAY PERFORMANCE

This table shows the performance of the relays for the cases illustrated in Figs. Ia to VIIIc, inclusive. The left-hand column in the table shows the various conditions which may call for relay action. The columns headed Ia to VIIIc show the performance of the relays. The term "o. k." indicates satisfactory performance. The numerals 1, 2, 3, etc., indicate abnormal performance which is explained for each case under the corresponding numeral in the Explanatory Note at the foot of the table.

	CASE																		
	Ia	Ib	Ic	Id	IIa	IIb	IIc	IId	IIe	IIf	IIIa	IVa	Va	VIa	VIb	VIIa	VIIIa	VIIIb	VIIIc
Short circuit																			
3 ϕ—Normal (or 2 ϕ)	o.k.	o.k.	o.k.	o.k.	o.k.	13	14	13	19	21	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	13	13
3 ϕ—Reverse (or 2 ϕ)	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
S ϕ—Normal $x\ y$	1	1	o.k.	10	1	o.k.	o.k.	o.k.	o.k.	o.k.	1		1	1	o.k.	1	1	o.k.	o.k.
$y\ z$ (or $y\ w$)	1	1	10	1	1	1	15	1	o.k.	o.k.	1	o.k.	1	1	10	1	1	1	1
$z\ x$	1	1	1	o.k.	1	16	16	16	1	19	1	o.k.	1	1	1	1	1	16	16
S ϕ—Reverse $x\ y$	2	2	o.k.	o.k.	2	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.		2	2	o.k.	2	2	o.k.	o.k.
$y\ z$ (or $y\ w$)	2	2	o.k.	6	2	2	o.k.	2	o.k.	o.k.	o.k.	o.k.	2	2	o.k.	2	2	2	o.k.
$z\ x$	2	2	5	o.k.	2	16	16	16	2	o.k.	o.k.	o.k.	2	2	5	2	2	16	16
Line to ground x	1-2-7	o.k.	8	8	1-2-7	7	8	7	o.k.	o.k.	o.k.	8	o.k.	1-2-7	8	o.k.	1-2-7	7	7
y	7	1-2	8	o.k.	7	7	8	7	7	8	o.k.	8	o.k.	7	8	o.k.	7	7	7
z	o.k.	7	o.k.	8	o.k.	o.k.	o.k.	o.k.	7	8	o.k.	8	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
Reverse exc. cur. trip	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
Reverse chg. cur. trip	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	17	o.k.	o.k.	17	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
Reverse chg. cur. reclose	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
Regulator displacement	3	4	o.k.	o.k.	11	o.k.	o.k.	o.k.	20	o.k.	o.k.	o.k.	o.k.	22	o.k.	o.k.	23	o.k.	o.k.
Phasing-in on impedance voltage	o.k.	o.k.	9	9	o.k.	12	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	9	o.k.	o.k.	12	o.k.
Cross- and reverse-phase protection	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	18	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	18

EXPLANATORY NOTE

1. The lagging relay trips on currents lagging greater than 60 deg.

2. The lagging relay will not trip on currents lagging greater than 60 deg.

3. All three phases are affected by the regulators. A phasing relay is required at z. The phasing relay cannot be added at x because the regulators normally add the voltage in the lagging direction, making it impossible to reclose at light loads. Omitting the phasing relay at x makes pumping of the network switches very probable because the voltage is added in the lagging direction. This combination is not acceptable.

4. The voltages at y and z can be added only in one direction by the regulators because of the ground being on B phase. At y the voltage is added in the lagging direction, preventing reclosure or causing pumping as explained in paragraph 3.

5. The relay at z will not trip on short circuit currents lagging more than 60 deg. It is probable that the x element of the two-circuit relay will have a greater tripping torque than the y element has closing torque which is produced by the load current.

6. Same as paragraph 5 except a different phase is involved.

7. There is a possibility of tripping when faults occur on the network near a transformer because of the auto-transformer action between the two halves of the secondary causing a reversal in the unaffected half of the winding.

8. It is not likely that the two-element relay will trip when faults occur on the network because of the greater torque of the affected element. The saturation of the current transformers renders the operation somewhat uncertain.

9. When the voltage difference on the lagging elements leads more than 60 deg. an opening torque is produced in the disk. This is, however, more than neutralized by the greater closing torque produced by the leading element up to 90 deg. lead at which point the torques are neutralized.

10. The leading element of the two-circuit relay gives a tripping torque for currents lagging more than 30 deg. As long as there is sufficient load to saturate the current transformer of the lagging element there is little danger of tripping.

11. The normal operation of the regulators adds the voltage in the lagging direction at x and z. The phasing relay at z prevents reclosure by boosting the voltage. If the phasing relay at z is omitted then the normal operation of the regulators may cause pumping because of the lagging voltage at x and z.

12. The relay at x will prevent reclosure on voltage differences leading more than 30 deg. if it is connected for phasing. If it is not so connected then the relay at z will prevent reclosure at voltages leading more than 60 deg.

13. The x relay will trip on leading currents greater than 30 deg.

14. The lagging element of the two-circuit relay gives a tripping torque for leading currents greater than 30 deg. but the leading element gives a greater closing torque until 60 deg. at which time the z relay will trip.

15. The same as paragraph 10 except the angle is 60 deg.

16. It is probable that all single-phase loads and shorts will lag enough to function properly.

17. Will not trip on reverse charging currents leading more than 60 deg.

18. The phasing connection across z might hold open for a cross from x to z. An extra phasing relay is necessary at x for holding out on a reverse connection.

19. The x relay will trip on currents leading more than 60 deg.

20. The relay at x will prevent reclosure at voltage differences leading more than 60 deg. if it is connected for phasing. It does not seem necessary to connect this relay for phasing.

21. Same as paragraph 14 except the ground and two-circuit relay are on B phase.

22. The regulators add the voltage in the lagging direction at x. The phasing relay prevents reclosure under normal conditions. Omitting the phasing relay at x may cause pumping under normal conditions.

23. Same as paragraph 22 except that z also is affected.

Such combinations as two single-phase regulators and Y-Y transformers are not included because it is not expected that Y-Y connection would be used on three-wire circuits and on four-wire circuits, the phase without a regulator being unregulated.

Conclusions

The simple watthour-meter type relay having characteristics similar to Fig. 5 is suitable for the tripping function and for the reclosing function when the incoming transformer voltage leads the network voltage. Under normal operating conditions, the incoming transformer voltage always leads the network voltage with the probable exception of the cases of the polyphase and two single-phase regulators at very light loads. A voltage may be caused in the lagging direction by the failure of regulator control or by reverse charging current when a breaker fails to trip. Failures of breakers and regulator control can be minimized by proper inspection and maintenance. Mechanical interconnection prevents trouble from regulators.

The relay characteristic shown in Fig. 8 prevents reclosing on incoming transformer voltages that lag the network voltage and is, therefore, entirely suitable for the reclosing function and may be used in cases where it is believed that characteristic in Fig. 5 will not be suitable. The network breakers being located at many points in subway vaults makes it desirable that the breaker with the relay equipment be kept at its utmost simplicity. The relay should not be designed to avoid trouble from the regulators, but the regulators should be mechanically interconnected or provided with an alarm device to prevent improper operation of the relays. The induction type relay constructed of watthour-meter parts is the most simple and reliable device known for directional characteristics. When it is realized that such a characteristic as that indicated in Fig. 5 can be obtained with standard watthour-meter construction and adjustments, involving only a different current coil and the replacement of the recording mechanism by standard relay contacts, every reasonable effort should be made to utilize it. Maintenance, testing, and adjustments are simplified. The characteristic of Fig. 8 has the objection of requiring an extra relay which, however, is just as simple in construction and adjustment as the other relays. To incorporate both features in one relay requires an entirely new development without the assurance of obtaining characteristics that are as definite as those of Fig. 8.

The author acknowledges valuable suggestions and criticisms from Messrs. W. R. Bullard and L. F. Kennedy who reviewed the first draft of this paper.

Appendix A

Diagrams Ia to VIIIc show the effect of regulator displacement on secondary voltages of the transformers. The diamond or rectangular shaped areas refer to the paths taken by the regulator voltages when they are varied from the neutral to the full boost position. It is not necessarily true, however, that the breaker cannot be reclosed by the regulator voltages being outside the area, because this depends on the relay characteristics and equipment. It simplifies the diagram to omit the other paths. The lines $T\ T$ for tripping and $R\ R$ for reclosing coincide in most cases. It will be observed that the ground on the midpoint of one phase of the delta secondary seriously changes the direction of the normal voltage added by the regulators as far as the reclosing function is concerned. A study of Table I will reveal that the delta-connected secondary is not as simple a proposition for the automatic type of network switch as is the Y-connected secondaries. Single-phase networks must also be given particular attention when the transformer primary is Y-connected. A special phase-angle for reclosing is necessary. The data under the figures apply to the regulator, transformer and relay equipment for the different combinations. In cases Id, IIc, IIf, IVa, and VIb, two element relays similar to Fig. 12 are used on some of the phases.

RESEARCH WORK TO BE EXTENDED

New activities to be undertaken in its research work by the Society of Automotive Engineers include assistance in the investigation of causes and prevention of highway accidents by the Highway Research Board, to which C. B. Veal, manager of the research department of the society, was appointed at the annual meeting to represent the society; investigations into improved automotive production methods and motor vehicle operation and maintenance; dissemination of popular information on the results of the cooperative research on fuels and their effect on engine performance, and perhaps studies of the psychological factors affecting the riding comfort of passengers in motor vehicles.

The membership of the research committee of the society has been enlarged considerably to further these and other investigations, such as headlighting, in which the society is now or soon will be engaged.

FRENCH EXPERTS PLAN RADIO TESTS TEN MILES ALOFT

The characteristics of wireless waves ten miles aloft are to be tested by French scientists. Aeronautical experts of the French army have arranged to send up a small balloon which will carry with it a very light radio set that will automatically send out signals. From a like set, signals will be sent at the same time from the ground. The signals from both sources will be carefully recorded and studied. From the experiment it is hoped to obtain information regarding the effect of atmospheric conditions on wireless waves that will aid both aviation and wireless. —*Telegraph & Telephone Age.*

Discussion at New York Meeting

PAPERS ON A-C DISTRIBUTION NETWORKS

(Fairman and Rifenburg,[1] Grissinger[2], Parsons[3], Bullard[4], Blake)[5]

New York, N. Y., November 11, 1926

J. C. Parker: I am quite sure from the remarks of Mr. Fairman that he would not want anyone to generalize from his description of what has been the engineering program of the Brooklyn Edison Company into a conclusion that the same medicine is good in all cases.

Some four years ago it was perfectly apparent that pressure of population was forcing and would continue to force an extraordinary growth of the portion of Brooklyn at that time served through converter substations. The sequel has proved fully that predictions made at that time were fully justified. One who gained his impressions of the central portion of Brooklyn in the years 1920-1922 would scarcely recognize the place today.

That meant that an already fairly dense territory which did lend itself to network development was bound to become very, very much more dense in the near future; buildings would be torn down, taking out their equipment, their wiring, and calling for extraordinary increases in the street supply lines to them. Then one had there a unique condition with reference to continuing the expansion of the then system of 25-cycle generation conversion and d-c. distribution, a condition which assuredly could scarcely be expected to find a duplicate in the Loop District of Chicago, in downtown Boston, or in the lower part of Manhattan Island.

That was one thing. For another, the company whose processes Mr. Fairman describes had a relatively small amount of 25-cycle generating equipment, that equipment not of the most efficient type. It was in process of developing a highly efficient 60-cycle generating station to take care of the equally rapidly increasing development in the peripheral sections of Brooklyn. Now, a process of curtailing the d-c. load, of actually diminishing it, would have been almost if not quite unthinkable had it involved the virtual scrapping of a large and highly efficient 25-cycle generating station. Such was not the case in the Brooklyn territory. Easily enough other uses could be found for the 25-cycle generating equipment.

One fact which may be mentioned here is that that equipment—not so good for energy production as the newer station being built—was just as good as anything else could have been for peak capacity through the use of a relatively small amount of frequency-converting apparatus.

Again, a system which had a large or preponderant 25-cycle generating capacity, could not anywhere nearly have adapted itself to the program Mr. Fairman has indicated.

Mr. Fairman's and Mr. Rifenburg's paper is not based entirely on prediction, but on a statement of fact accomplished as well.

The experience of the four years with a radial a-c. system has demonstrated an excellent standard of service resultant from the exquisite attention to detail which is absolutely necessary, of course, with any system that is to provide continuity of service for the customers.

The capital savings which should have resulted from the changes indicated in the paper are matters of past experience and of accounting record. The economy in operation indicated in the paper is also up to and inclusive of the year 1926, as a matter of fact.

I should suggest, again to avoid the danger of generalization, that in looking at the efficiency curve in the paper under discussion, one do not extrapolate indefinitely. I think it would be in the minds of the authors that that curve should flatten out rather speedily in the neighborhood of the year 1930 unless, indeed, they have in mind further and marked improvements in their distribution design which will raise the efficiency ultimately to something in the neighborhood of the upper nineties; that, I believe, they do not expect.

Speaking of the future, may I suggest that discussions of a-c. network problems at the present time seem to concern themselves primarily with what is to be recognized as a *sine qua non* of service; namely, continuity; and that the network development seems to be regarded as something we must have to bolster up our a-c. systems. In so far as the developers of networks stop there, I think they make a mistake and miss at least a half of what these networks will offer in the future.

My own thought, and indeed I believe the plan in the minds of the authors of this paper, is that ultimately the network will accomplish very much more than described here.

Probably the tripping out of a network switch on the relatively small currents involved in the magnetization of transformers will be thrown overboard for things of considerably greater value. Those things, it seems to me will express themselves in a system which again will become a radial system, but inverted from present practise. If you please, we may consider the network as the center of the system and working backward over the transmission feeders reach generators which will not be connected together within the power house.

In the attempt to limit switching requirements in our generating stations we have indulged in a semi-isolation of generators. We have got to the point where the rupturing capacity of circuit breakers seems nearly to have come to its limit, and where the further aggregation of generating capacity on one bus seems not sane if indeed it be physically practical.

Now, the development of the network offers a way out. In the extreme one may consider an individual generator of 160,000 or 200,000 kv-a. capacity with fifteen to twenty feeders of the size described by the authors of the paper, these feeders going directly to the distribution system and tying these larger generators to the distribution network without any use of a generating station bus.

With some necessary details to be worked out and with the routine tripping of feeders from the network by the deliberate imposition on them of regulated short circuits at the generating station, I think such a program as that offers a solution of one the most vexing and perplexing problems of generating station design today.

I venture the prediction that within another decade we shall find that the development of these a-c. networks, initiated for the purpose of procuring the utmost continuity of service to the customers, will have proved itself more valuable in its concomitant effects than in the principal object for which it has been undertaken.

A. H. Kehoe Nearly every presentation on a-c. networks up to the present has set up some extensive area which is to be entirely networked. Since a reasonably dense loading is required before transformers can be connected economically to a single set of mains, the districts where this is practicable seem at first sight to be limited to a few of the larger cities. I do not believe, however, that networks will be restricted to zones of this character. Economical considerations arising from savings possible in other parts of the system are forcing the use of this arrangement in the smaller communities where the increased reliability would otherwise be ignored. In districts using 2300- or 4000-volt distribution from substations that are themselves supplied by lines of 27-kv. or less, it is possible to avoid any additions to the existing substation capacity by supplying new distribution transformer requirements directly at the voltage in use to feed the substations. To do this, a few distribu-

1. A. I. E. E. Journal, January, 1927, p. 39.
2. A. I. E. E. Journal, January, 1927, p. 46.
3. A. I. E. E. Journal, January, 1927, p. 50.
4. A. I. E. E. Journal, January, 1927, p. 17.
5. A. I. E. E. Journal, April, 1927, p. 361.

tion transformers in several of the small but more densely loaded sections of the community have their secondary lines joined into a network which makes it possible to replace part of the existing capacity with transformers supplied at the higher voltage. All new capacity required can be added in this manner, and the part of the low-voltage (2300/4000) capacity which is released can be used when required in the less densely loaded sections. The economies indicated in the Fairman-Rifenburg paper can be realized in the smaller cities by adopting this so-called "high-voltage infiltration" method even where the supply is overhead. The arrangement results in lower costs than any which are being obtained with the standard radial distribution, and gives greater reliability of service to the more densely loaded districts.

I want to express my belief in what Mr. Parker has described as the ultimate arrangement of the supply systems which will feed our larger distribution networks; but at the same time a word of caution is required, as this method of operation has never been completely demonstrated, to my knowledge, either by calculation or by operation. Those of us who have been studying its possibilities for the past two years are positively hopeful of obtaining as successful results in the supply system as have been indicated here for the distribution system. It is important in selecting network switches and relays to realize the extreme probability of their future use on systems having sources tied only at the load. It is hoped that this subject, which is being considered in one of the committees of a companion organization at present, will have been more fully investigated before another year has passed.

I do not agree with the opinion expressed that the sensitive reverse-energy feature is the point of attack in looking for improved relaying of network switches. The phasing or synchronizing characteristic required up to the present (and these requirements seem to be growing stricter) makes it necessary to have a very delicate relay. So long as this cannot be avoided, I believe it preferable to use a low value of reverse energy.

With the publication of the Fairman-Rifenburg tests, I believe ample data have been presented to be certain of the factors involved in lamp flicker or the elimination of faults on low-voltage, a-c. cables. In making their tests, however, I regret that the authors did not investigate the situation which may occur at induction motors during the time when a single-conductor main is clearing a fault near the motor service. This phase-converting action was discussed at the 1925 Saratoga meeting of the Institute and is emphasized here in order that anyone attempting the expensive procedure of obtaining secondary cable fault behavior will obtain and publish information on the effects of line-to-neutral secondary faults upon loaded polyphase induction motors operating adjacent to the fault.

Mr. Parsons: I should like to ask Mr. Fairman what proportion of the Brooklyn Edison Company has been converted into the new system and what proportion probably will eventually be changed over.

Henry Richter: The last four papers in this session deal mainly with that part of the a-c. network system from the station to the network unit. They apply particularly to two important problems; namely, primary system design (in which I include the distribution transformers) and the automatic network protective device. The third element of every a-c. network is the secondary system, and operating engineers have found it necessary to give this third problem at least as much study as has been required for either of the other two.

There is a decided interrelation between these three subjects. When the relay and network unit developed for one type of network system are considered for other installations where differing arrangements of the secondaries are contemplated, the construction of both relay and unit must often be considerably changed to meet the requirements.

In determining which type of secondary system should be adopted for the network, many cities are choosing that scheme of connection and voltage which fits in best with local conditions at the present time. This is only natural with the network art so new. But it is introducing a complexity in apparatus requirements that threatens to parallel the chaotic lamp and frequency situations of some years ago.

The secondary systems thus far adopted include two-phase and three-phase, combined light and power mains and also separate light and power mains, star- and delta-connected combinations for three-phase, and even differing voltages for the three-phase, four-wire, star-connected, combined light and power scheme.

Should these various secondary systems be adopted extensively and the groups of cities employing each scheme come to require guarantees on satisfactory operation of network and utilization apparatus, three major disadvantages will result.

First, there will be the numerous differing requirements in master relay and network-unit design already mentioned. Second, there will be a great increase in the complexity of manufacturing and applying all the devices connected to the secondary system, affecting not only the consumers but also the operating companies. Third, there will be lost the progress that usually attends concentration of efforts towards improving the best type of system and equipment available.

A number of the operating company engineers intimately interested in a-c. networks are coming to recognize the advisability of standardizing on one secondary scheme of connection and voltage. But each claims his own system is the best and should be the one chosen as the standard. That also is natural.

As a result of numerous requests for information bearing on this problem, an analysis of the situation as it affects the utilization devices and distribution apparatus connected to the secondary mains was started 2½ years ago. It was soon found that the effect of the various schemes on general-purpose motors monopolized the attention of many of the operating engineers who were also working on the problem. On the contrary, there are several other types of equipment each of which is affected just as much as are general-purpose motors.

It was also discovered that the apparatus situation in the future is at least as important as the possibility of having present standards suffice should a given scheme be applied to all existing distribution systems. And, finally, in the effort to make an impartial and complete analysis of the effect of all factors on the electrical industry as a whole, it appeared impossible to disregard the commercial aspects.

This study is scheduled for presentation at the 1927 Winter Convention of the Institute. The object of the paper is to promote widespread discussion of the subject. This, it is hoped, should result in a clarification and should assist those operating engineers who have come to recognize the great benefits that would attend standardization for network secondary systems.

Mr. Bullard suggests standardizing on one type of network relay. Similarly, and without wishing to detract from the specific discussion of the subjects of these papers, I recommend that the same problem as regards secondary systems be given the attention of the Institute along with network relays and network units.

H. R. Searing: The experiences of the United Electric Light & Power Company, of New York City, with network switch and relay operation covering a period from April 1922 to the present time is as follows:

We have 21,209-kv-a. transformer capacity in network operation, 350 switches installed, 253 of which are in automatic operation, with an estimated peak load of 17,000 kv-a.

These feeders serve several different kinds of networks,—some three-phrase, some two-phase, and some single-phase. They are served not only by 2750-volt primary circuits but also by 13,200-volt circuits. We now have a transformer capacity of 2950 kv-a. and a total of 25 switches in service on 13,200-volt feeders. On the three-phase, four-wire system,—that is, the part of

the system converted to combined light and power,—there are ten circuits with a transformer capacity of 11,121 kv-a.

The first 13,200-volt bank was cut in April 1, 1926, and the 13,200-volt feeders parallel the 2750-volt network. In this connection, before I go into the operation of relays, I might say that in operating 2750- and 13,200-volt circuits in parallel, we have had no trouble, the 13,200-volt transformers with 10 per cent reactance paralleling the three per cent distribution transformers on the secondary network.

On switch operations from January 1 to September 30, 1926, there were a total of 40,360 switch operations which were obtained by 4838 circuit operations. Ordinarily this is accomplished by dropping circuits over the midnight watch every night, so if there are ten switches on a circuit, there will be ten operations every night. Some circuits cannot be dropped. There may be two-phase power and other lighting load not networked, on the circuit. During the 40,360 operations, there was a total percentage failure to open of 0.263 of one per cent; a percentage failure to close of 0.149 of one per cent, which you will see is a pretty good operating record. The percentage of failure to open is not significant, because, if a switch fails to open, it is backed up by fuses which will blow and clear. The switch which fails to close is a hazard.

In the period from 1922 to date, we have had twenty-four primary faults; that is, faults where a circuit tripped out, which, under the radial system, would have caused an outage to a customer, and of these faults, twenty-one cleared without blowing any network switch fuses. With three faults, one fuse on one switch was blown.

We have had eleven secondary faults. Nine cleared themselves and two cleared and blew the fuses on the switches nearest the fault. We have had one equipment failure and it cleared itself without outage. We have had two operating faults, due to station switches dropping out or being opened by mistake.

One of the gentlemen spoke of the maintenance problem. While it is realized that there are many relays on a network, it is not fair to compare the network relays with the relays on the network feeders as regards maintenance, because backing up that particular feeder relay are relays all the way back to the generating station and each circuit has a certain percentage of the relays back of it to be considered when talking about relay maintenance.

We found it was necessary to breed a new type of repair man; a man who not only could work on relays, but could also adjust the switch and was safe to go into a transformer vault with high-tension equipment. I don't think that the industry is going to find that the ordinary test man or meter tester who maintains generating and substation relays, will be satisfactory for the maintenance of network switches. A mechanic is needed,—a man with mechanical ability as well as test knowledge.

G. R. Milne: I should like to discuss in general the papers on network relay characteristics and in particular the paper by Mr. Blake.

First of all I should like to talk of the operating characteristic of the relay. It is pretty well agreed, now, among those familiar with network development, that the desired opening characteristic is that of a simple watt-hour meter. The method of obtaining that characteristic, however, is not quite so simple; for instance, the statement is made in the paper by Mr. Blake that this requirement can be met by the watt-hour meter operating in connection with a saturating current transformer.

Now, it is true that watt-hour meters when operated with current transformers of the non-saturating type give this characteristic. Yet, when, in order to protect the network relay from short-circuit currents, it becomes necessary to use a current transformer of the saturating type, there must of necessity be some difference in the curve of opening from that of a true watt-hour meter. We are all familiar with the saturating characteristics of iron and, therefore, while the diagrams indicate that the opening characteristic is a perfectly straight line, there must have been, of necessity, some change or variation in the shape of the opening characteristic at low values of current at which the relay is at times required to operate.

To come to the closing characteristic of the relay; one of the fundamental requirements is that when the relay closes, the system conditions should be such that the transformer will feed true power into the network. That is necessary to prevent pumping of the relay—*i. e.*, alternately opening and closing particularly on high-voltage feeders of the order of 13,800 volts or above. Such pumping will occur in openings on 13,800-volt network feeders and such pumping will occur provided the watt-hour closing characteristic is continued.

Of course, there are various devices by which to get around that, and one of the methods suggested is that of closing in the feeder immediately to prevent pumping. That cannot be done if the feeder trips out on a ground fault, and since, in going to higher-voltage cables, we shall probably predominate in single-conductor cables, most of the troubles will be line-to-ground faults, and, therefore, it is not possible for the operator to reclose to prevent the pumping.

Then, to look at the development from a broader angle, two of the previous discussors have indicated that the possible future trend of network development will be to tie the generating sources only through the low-voltage network. When this is done, we must have a relay which is pump-proof, not only throughout limited angles of operation such as we can impose on the relay on our present systems, but we must have a relay which shall be pump-proof throughout the entire 360 deg. which may occur in relay operation. When the sources are out of synchronism, it is possible to have currents and voltages throughout the entire 360 deg. and, therefore, backing up what two of the previous discussors have said, it is necessary not to bridge the subject of what is the most desirable type of characteristic to incorporate in a relay, but get together and decide what are the desirable characteristics not only for the systems we are operating at present, but for the systems as we see them in the future. It is obviously undesirable to get a large amount of equipment on the lines and then decide we want to change the method of operation and find that the limitations originally imposed in the relay, prevent it from being used on the new system.

H. C. Forbes: The experience of the New York Edison Company in the design and operation of a two-phase, five-wire a-c. network has brought out some points which are of interest in connection with the papers on distribution.

The network of which I am speaking is somewhat unique in that it is supplied by both 2300-volt, two-phase feeders, and 13,200-volt, three-phase feeders, the latter being connected to the network by means of Scott-connected distribution transformers. This arrangement has enabled the retention of the investment in the 2300-volt equipment and at the same time has permitted the future load growth to utilize the advantages of the higher distribution voltage.

The 13,200-volt feeders have already demonstrated the fact that if one network switch sticks in the closed position when the feeder switch is opened, the remaining switches on the feeder will undergo the pumping action, which was expected and the causes of which are explained in Mr. Blake's paper. In case this happens, however, it is usually possible to remove the feeder from the network by connecting the regulator to the feeder at the substation and allowing its exciting current to flow from the feeder to the regulator. The reverse energy is usually sufficient to trip the switch. In the case of a lower distribution voltage, an intermediate transformation at the substation is usually involved. Here, if a network switch fails to open, it may be possible to remove the feeder from the network by energizing one of the substation transformer banks from the feeder. The procedure would be to put a spare transformer bank on the emergency bus at the substation and excite it from the feeder which

is giving the trouble. Unless the relays are badly out of adjustment, the network switches will be then tripped.

I should like to call atttention to one point Mr. Blake has mentioned in his paper; namely, that the relays must be designed to meet the worst conditions of lag on short-circuit current which, as he points out, will occur when the fault takes place at the terminals of the transformer. The example which he cites of a transformer having one per cent resistance and 10 per cent reactance, while obviously correct, may be misleading. This is true because the distribution transformers in use are frequently of 10 per cent reactance, but, nevertheless, a portion of this is often external to the transformer in the shape of iron washers slipped on over the leads to the transformer. This type of reactance is effective in obtaining the required distribution of load among the transformers but in case of a short circuit, the iron washers become saturated and will have little effect in determining the phase angle of the short-circuit current. The inherent reactance would be the predominant factor in calculating this phase angle.

Our experience to the present time has indicated that very little mechanical difficulty is to be expected from the switches, but that on the other hand, there is likely to be considerable difficulty in the adjustment and maintenance of the relay. It is to be hoped that closer cooperation between the engineers of the manufacturing companies and the operating companies will result in a simplified design of the relays which will obviate some of these difficulties without sacrificing any of the characteristics the relays are intended to supply.

J. A. Brooks: The design of the Brooklyn Edison Company's low-voltage network, as described in Messrs. Fairman's and Rifenburg's paper, being different in many details from a-c. networks now in operation gave rise to new problems in switch and relay design, the solutions of which while not difficult may be of general interest.

The network transformers being connected delta on the high-voltage side and star with neutral grounded on the low-voltage side causes the direction of power flow on the low-voltage side to be from the network into the transformer in one phase and from the transformer into the network in another phase for single-phase line-to-line or line-to-ground faults on the high-voltage side, the phases referred to on the low-voltage side being taken from line to neutral. Since the present single-phase network relays have potential coils connected from line to neutral on the same phase in which the current coil is connected and since they are necessarily arranged to trip on true power flow due to the wide range in power factor within which the relay must trip the switch, these primary faults would cause not only the network switches which are associated with the particular feeder in trouble to open but would also momentarily open switches not associated with the particular primary feeder in trouble if single-phase relays were used. In order that such misoperation may be avoided one three-phase network relay will be used per switch instead of three single-phase relays. The use of three-phase relays may in some cases cause the switch to close with one fuse blown or not to open until after the breaker at the generating station opens, but these features are not considered objectionable.

The charging current of the 27,000-volt cables feeding the network will in most cases be greater than the combined exciting currents of the connected transformers which, since no regulators are used, would probably cause pumping similar to that mentioned by Mr. Blake. A separate relay similar to that described in Mr. Blake's paper will be used to overcome this difficulty.

Since the network switch is to be located in the low-voltage pothead of the transformer, the transformer temperature will materially affect the operating temperature of the switch in that the fairly high heat conductivity of the copper connection between the transformer and the switch contacts will cause the switch to have a temperature approximately that of the transformer copper, and the temperature of the air inside the pothead will probably be somewhat higher than it would be otherwise. Under full-load operating conditions the temperature of the switch contacts will be above that permissible for the ordinary type of copper leaf contact, necessitating the use of a type of contact which will retain its contact pressure at these temperatures and will not be seriously affected by oxidation. The relative high temperature of the air inside the pothead makes the use of special relay coils necessary.

There has been some discussion relative to the desirability of synchronizing generating stations through the low-voltage network. This problem if load other than the network load were taken from the generator station bus, would not only involve suitable closing characteristics of the network relays, as pointed out in Mr. Bullard's paper, but would also involve tripping characteristics differing from the present practise. Under these conditions there would probably be a normal exchange of power between generating stations, the direction of which may change with the hours of the day. Under such conditions it may be necessary to give the relay a trip setting for much greater magnitude of power flow and longer time than is now being used. Where the network transformers have delta primaries with the neutral grounded at the generating station only, the short-circuit currents passing through the network switch for single-phase line-to-ground faults on the primary feeder may not be as great as the float setting necessary to prevent the relay tripping on normal exchange of power between the generating stations. The desirability of attempting to accomplish these added features in the present network relay is questionable, assuming that it can be done.

D. K. Blake: At this time I want to discuss Mr. Fairman's paper along the ideas mentioned by Mr. Parker, Mr. Kehoe, and others. This morning in our discussion we have just one type of network under consideration with these elements: a secondary grid, a protective breaker, a transformer, and the primary cables.

We are thinking these days about an ideal system or a fundamental plan for the system. Some engineers believe some such thing as is being done by the Brooklyn Edison Company is the ultimate ideal.

Now, there is a certain load density—I don't know what it is—at which the low-voltage network is economical. Then the question arises when considering the low-voltage networks as an ideal system—what is the ideal or fundamental plan to take you over that period of time from period of low density up to the low voltage secondary network density?

I believe that the same idea of network grid, protective breaker, transformers, and cables can be applied. In other words, the d-c. Edison network has demonstrated throughout these years that the ideal distribution system is a network. A load can be tapped at any point and the network can be reinforced at any point according to the location of the loads.

The idea I had and have studied to some extent—and other engineers are thinking along the same lines—is that we would have exactly the same kind of network as the low voltage network except it would be at 4000 volts to take us over the 625-kv-a. per square mile density up to the 4000 kv-a. per sq. mil. density if that is the minimum density for the low voltage network. In the low-voltage, a-c. network you can burn off a fault on the network mains but at 4000 volts you can't do that. The difference comes here, that you put in at the end of each main where they are interconnected, an oil circuit breaker with plain induction type overload relays and the transformer feeding the interconnected point would have the usual oil circuit breaker overload and reverse power relay.

Then we have a 4000-volt grid like the secondary grid and you start out with certain transformer spacings. As you continue to grow, you decrease the transformer spacing. Your transmission system would be simply a network feeding point, a trans-

former, and a high-tension cable back to your generating station. This is in harmony with the idea of synchronizing at the load.

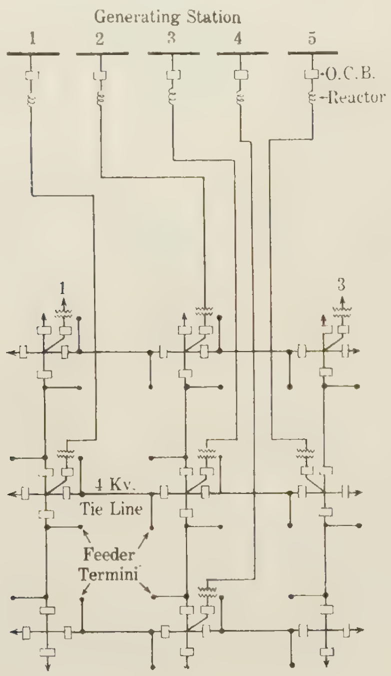


Fig. 1

Fig. 1 shows the connections. The feeding points would be small substations consisting of a three-phase transformer and five truck type panels.

C. A. Corney: I should like to ask Mr. Fairman how his company, in the ultimate development of the network, would take care of large office building or hotel load of the magnitude of 1000 to 1500 kv-a., and also how they would serve a customer whose secondary circuits would require higher than 220-volts for distribution to motors. I would also be interested to hear a little more about how they can do without regulators on the primary circuits and still maintain standard voltages near the generating plants and at some distance from them.

R. K. McMaster (communicated after adjournment): In the discussion following the presentation of the paper the possibility of the new developments having an unfavorable effect on the standardization of equipment was mentioned.

It is possible to build three-phase motors with windings which can be connected parallel-star for 190 volts and series-delta for 220 volts. To promote interchangeability it is suggested that this arrangement be adopted wherever practicable, at least to the extent of providing for a change from either voltage to the other by changing only a minimum number of connections between the coil groups and between these and the terminal leads.

The standard lamp voltage adopted by the National Electric Light Association is 115 volts and the corresponding line-to-line voltage of a four-wire system is 199 volts. The suitability of 190-volt motors for use on 115/199-volt circuits would be the same as that of 110-volt motors on 115-volt circuits or of 220-volt motors on 230-volt circuits. Although 120 volts is a recognized exception to the standard lamp voltage the use of 120/208-volt circuits should be considered as a temporary expedient and not as a standard. Otherwise there would be disadvantageous conditions with regard to lamps and various single-phase devices, without completely justifying the continuance of present standards with regard to motors.

Even where transformers are installed for power only the use of the star-connected grounded-neutral secondary connection has an important advantage from the standpoint of safety. This is that the maximum voltage to ground is comparable to that on lighting circuits. This advantage makes it desirable to contemplate the ultimate elimination of the delta connection of transformer secondaries. Such a change would involve less difficulty if made along with a complete change from 220-volt to 190-volt motors than it would otherwise. A complete change from two-coil to three-coil protection for three-phase motors is also very desirable.

A rating of 190 volts for three-phase motors is preferable to a rating of 199 volts, allowing a somewhat greater combined transformer and line drop for motors than for lamps rated at 115 volts, without involving the question of motor performance at less than normal voltage.

G. J. Newton (by letter): The three-phase, four-wire system of secondary distribution has long been the standard method in many places abroad; several years ago I made an inspection of several systems in England and in Dublin, Ireland. The recent development of a network protector has made it possible to adopt this system in American practise without any radical change in equipment.

While it is most desirable that the network protector be made as near perfect as possible still the true economy of the system as a whole will never be reached until proper study and care is given to the other parts of the system. Practically all of the existing underground systems show a decided lack of any real engineering ability in their design and consequently the first cost has been out of all reason.

I believe that now, at the beginning of the adoption of this system, is the proper time to work out some system of standards for all of the various parts entering into the system. A study of the various systems that, so far, have been installed in this country shows that each system is following different methods as to the amount of equipment, etc., that is used at feeding points, and unless a systematic method is decided on the ultimate result will be a large variety of methods.

The system as a whole permits of exceedingly simple arrangement of equipment in vaults; the reduced amount of cable, conduit, equipment and supplying the street lights from the secondary mains all tend to a greater economy if properly designed.

With the exception of the necessity to meet local conditions as to the location of vaults, manholes, etc., it may be said that one standard system would serve practically all cases with slight modifications to meet these particular requirements. Therefore I would strongly suggest that a committee be appointed to make a very thorough study of the general requirements and try and work out some standards to be followed in future work.

Unless something of this nature is done the result will be fully as bad as the existing conditions where each system has been installed as a unit and no attempt made to standardize any part of the work.

There are many existing systems that can be easily and economically changed to the three-phase, four-wire system if there is a standard method devised and while on these particular systems it may not be economically possible to comply with every particular still there would be a guide to work by and every effort could be made towards the standard practise approved.

Where entirely new systems were installed, they could, in most cases, follow the standard method entirely, it is only in the changing of existing systems, where present cable and equipment must be used that any serious difference need be adopted and even then it is believed that a close approximation could be secured by careful study.

From rough estimates that I have made recently I think that a properly designed three-phase, four-wire system can be installed complete for something less than 75 per cent of the cost of the average separate lighting and power system as now installed, and provide fully as much reserve capacity.

The three-phase, four-wire system equipped with the network protectors provides practically the same reliability as the old d-c. system with the added advantage of the economy peculiar

to the a-c. system of feeders; if to these advantages is added a reliable method of street light supply and control from the secondary mains you have an ideal economical and efficient system.

Based on over twenty-five years' experience in the design and construction of underground systems, it is my belief that it is possible to develop a standard method of handling most of this work so that the people interested in the work will have some kind of a guide to work by in either changing their present system or installing an entirely new one.

S. B. Hood (communicated after adjournment): In reading over this paper, and also the companion paper by D. K. Blake, the impression is left with me that the a-c. network of the type for which these relays are designed requires a form of relay in which the major part must consist of brains.

I do not question in the least the ability of our designing engineers to develop a form of relay that will be assuredly reliable in functioning under all the multiplicity of conditions that both authors point out as existing, or liable to exist, in the a-c. network. It does seem to me however that numerous precision adjustments must be required in the ultimate form of relay in order that it may function properly under every possible condition that may exist locally at the point of installation.

The difficulty I can foresee is our inability, as operating engineers, to get maintenance men with brains commensurate with those built into the protective device.

Mr. Bullard mentions that the relay can be materially simplified by modifications in the system or other apparatus used therewith. This is a feature on which I believe a word of caution is opportune at this time. We must be very careful in this development of a new form of distribution system that we do not permit "the tail to wag the dog."

The primary system, where network protectors are used, requires inherently a greater footage of cable for a given load density and area served than does a loop primary system. To this extent at least the network protector form of system is already burdened, although this burden may be nullified through elimination of high voltage switches in the various transformer vaults.

In the initial development of the network protector type of system a minimum of three primary feeders is essential. This means that at 4000 volts the initial development, to be economical, must be of at least 6000-kv-a. capacity. If 13.2 kv. is the primary voltage used then a minimum initial economic development of not less than 12000 kv-a. is indicated. In many cases such a large initial development is very hard to justify and may lead to retention or enlargement of existing direct current networks.

With the loop system, either of the type used in Minneapolis, or that in an even simpler form as used in Philadelphia, the initial development may be relatively small and the system can be extended as required very economically. Further, the loop system can be developed successfully with standard protective equipment of moderate cost and proven reliability. The use of pilot wires between vaults assures effective and reliable system protection with none of the uncertainties or refinements which the authors of the two papers under discussion point out. Since transformer vaults in a network are relatively close together the pilot wire investment is very slight, and more than offset by the lower cost and increased reliability and simplicity of the relays.

During the four years the Minneapolis loop system has been in operation the service has been almost 100 per cent perfect, and the few partial interruptions that have occurred have all been due to unwarranted functioning of the protective system. In other words had the system been installed with no protection whatever, in a manner similar to that now usual with direct current networks, we would have had an absolutely clean sheet as to service reliability. I am not advocating elimination of all protective devices, but merely wish to point out that a complicated or super-sensitive protective system will in itself inevitably cause more interruptions than it will save.

Both authors repeatedly bring to the fore the apparent characteristic of the network protector system to "pump" or "see-saw." This characteristic is at least absent in the loop system network.

In Mr. Blake's paper he mentions that "the normal operation of the regulators would cause no trouble. It is only in the rare condition where a regulator runs to full buck by some means that trouble is caused." The standard automatic induction regulator as furnished us today has a device on it that does exactly this every time the feeder is cut out. The object being to prevent picking up a heavy load of cold tungsten filament lamps at full or boosted feeder voltage. Apparently if we are going to avoid the trouble mentioned byMr. Blake we must cut out this device on our standard regulators.

One of the factors in the network protector relay that seems to introduce complications is that of having it function to open the breaker on transformer core loss. Are we not placing too high a value on core loss savings effected by opening part of the network feeders during light load. The actual value of this core loss at best is the fuel value in the energy we are trying to save. No system capacity or other operating costs will be eliminated. In large systems where such an a-c. network would be used, this item is at most less than one-half cent per kilowatt-hour. Taking a transformer vault of 300 kv-a. capacity the core loss saving by cutting it out one-half the time would only amount to approximately 4000 kw-hr. per annum, with a possible value of $20. Since this saving would have to be spread over two vaults, one being always in service, the actual saving per vault would run around $10 per annum. It must be clear therefore that if the building into the protective system of ability to automatically cut out on core loss exceeds much over $100 per vault or equipment it becomes an economic loss.

In so far as ability to kill an entire feeder by the simple opening of the main feeder breaker is concerned this is of very questionable value since our safety regulations do not permit, and should not permit, men working on a high voltage circuit with the only protection a switching device that is held open by automatically reclosing control equipment that may function without warning. It follows therefore that in order to work on a network feeder of the type under discussion every vault on that feeder must be visited and the breakers "blocked" before clearance is given the crew. With the loop system but two vaults need be visited in order to definitely clear any section of the primary loop, and but one vault is deprived of its supply as compared to a possible one-third the total number of vaults in the network protector system.

Unquestionably the manufacturer will solve all the many problems involved in the development of this new protective device if the distribution engineer will cooperate fully with him; but the great question that persists in my mind is—do we really need this development or are we overlooking the use of something that we already have that will do the same work as well or better?

J. F. Fairman: In answer to Mr. Parson's question as to what proportion of the system has been converted into the new system and what proportion will eventually be changed over, I understand that the question refers to the d-c. to a-c., and two-phase to three-phase change overs, inasmuch as the new network system will not be ready for service until the summer of 1927. In the period from 1922 to 1926, the d-c. load has been reduced by 22 per cent. Two-phase primary feeders have been completely changed over to three-phase and the a-c. system load has increased 280 per cent and, at the present time, is 78 per cent of the total system load. These changes, together with doubling the transmission voltage on the 60-cycle system, account for the 4 per cent increase in system efficiency. By 1935 it is estimated that the network will have been extended to cover approximately

two-thirds of the area of Brooklyn and will carry a load of 500,000 kw. The existing 360,000-kw. capacity of the a-c. substations will be used to take care of large customers buying power at 4100 volts, and the remaining overhead area outside of the network zone.

In answer to Mr. Corney's questions, the accompanying diagram shows the layout which is being used to take care of large office buildings or hotel loads of the magnitude of 1000 kv-a. and above. where the utilization voltage is 120/208. This amounts to a little network in the customer's vault which will be tied into the street network when this is available. These transformers will initially be fed by different 4100-volt feeders from the existing substations and may eventually be supplied by the 27,000-volt network feeders. Each bank will have a capacity of approximately 500 kv-a. consisting of three single-phase transformers or one three-phase transformer, as may be most convenient in each case. The same network switch that is used in the street will be used in these vaults. It will be noted that in the layout shown each bank and the street network is able to contribute equally in case of an outage of another bank. Thus, the outage of one bank will put on to the street network a demand less than the capacity of one of the units of that system.

In the case of customers requiring a higher utilization voltage, we shall continue our present practise of supplying power at

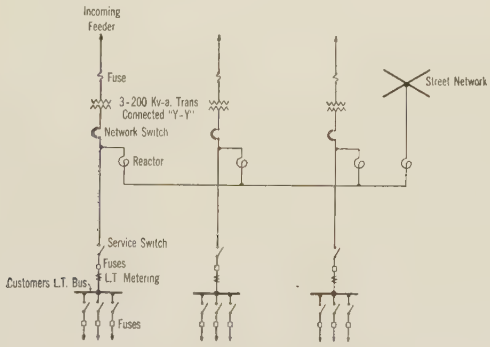


FIG. 2

4100 volts on a high-tension contract, and the customer may arrange his own circuits and his own voltages to suit his convenience. For large customers there would probably be more than one feeder and, as in our practise, we would study the particular case and make our recommendations to the customer as to how he could best accomplish the desired result. Again, such customers might eventually be supplied from one or more of the 27,000-volt network feeders.

With reference to voltage regulation and to the fact that no regulators will be used on the 27,000-volt feeders, I should again call attention to the fact that the drop in these feeders is negligible. The three-phase, 500-kv-a. transformers have an impedance of 5 per cent. The secondary mains have impedances of the order of 5 per cent per 100 ft. The typical city block is approximately 250 x 700 ft. From these figures it may be shown that, with a hand-regulated bus in the generating station, the voltage regulation on the network will be within plus or minus 4 per cent under ordinary conditions.

Without going into detail, I should like to say that we have anticipated Mr. Newton's suggestion and have worked out a plan for street lighting from the network, which we believe will render the same reliable service to the street lamps as we render to the other customers from the network system.

Mr. Hood's statement that the loop system can be installed at lower cost may be true initially but when one considers a system growing as rapidly as the one described, it would be unwise to let the initial costs outweigh the ultimate costs. The system we propose requires an investment somewhat less than the loop system, assuming a primary voltage of 4100 volts. The difference would be greater with higher primary voltages since the cost of the primary switches would be greater.

There would seem to be no justification for the statement that the relays for a loop system are more simple and reliable since both systems use induction-type relays.

We agree with Mr. Hood that savings in core loss would not justify using a relay which would open the network circuit breaker on transformer core loss. It does seem, however, that this characteristic would be most useful on a system of the kind we are proposing, in which there will be between 30 and 40 transformers on each primary feeder in the ultimate development and these will extend over a distance of several miles. It would be a most laborious process to have to open these switches by hand in case it was desired to work on the feeder or a transformer. We would call attention again to the short-circuiting and grounding switches in the high-tension potheads in the transformers. After the station breaker has been opened and the network switches have opened on magnetizing current it is only necessary to short circuit and ground the feeder at two adjacent transformers to work safely on the section of feeder between those transformers, or to ground the feeder at the first transformer and the generating station to work safely on that section of the feeder. These grounding switches are of ample capacity to stand the short-circuit current which would flow if any number of the network breakers or the station breaker had not been opened in advance. Further, these grounding switches will be operated from the street outside of the transformer vault, thus assuring further safety to workmen.

G. G. Grissinger: Supplementing my paper, it might be interesting to note that there are a number of network systems throughout the country in successful operation, particularly in points like New Orleans, Memphis, Dallas, and, of course, in New York where it originated, and that in a number of cases on both 4000- and 13,000-volt feeders, primary feeder faults of a serious nature have been cleared satisfactorily.

J. S. Parsons: The theory on which the design of the present network relay is based is fundamentally correct and the development is now well past the experimental stage. Much valuable experience has been gained from the 1000 or more network relays now in service. In view of this experience, I think there will yet be developed a network relay, using the same fundamental principle, which will not place limitations on the design of the network system. It is necessary that such a relay be developed so that the network system can grow to its ideal form and allow the network to be fed from different sources of power and synchronized at the point of load.

W. R. Bullard: In attempting to describe the complex duties which may be imposed upon the prospective apparatus in network systems of the type to which these papers apply, it is very difficult to avoid leaving the impression that the apparatus itself must necessarily be very delicate and complicated. As a matter of fact, in spite of its complex duties, this device really is a relatively simple piece of apparatus.

Such matters as phase angles, for instance, are taken care of by simple adjustments in the constants of the relay circuits. These adjustments can be taken care of at the factory, chiefly as a matter of initial design and need not concern the operating man, providing the proper coordination is maintained between the designer of the distribution system and the designer of the relays. The sensitivity necessary to provide opening on magnetizing current of transformers can be provided by an exceedingly simple type of current transformer which gives relatively high values of relay current at low values of line current. The sensitivity necessary for the closing operation is obtained by an even simpler device.

It is only necessary to refer to the figures on percentage failures given in Mr. Searing's discussion to show that this apparatus is making an excellent record as regards performance in actual

service. And in this connection I wish to emphasize one point in particular,—namely, that the operating failures that have occurred and are occurring do not affect the service reliability of the system. In other words, the customer never knows about them. This is undoubtedly due to the fact that in this type of system the idea of placing the responsibility upon a number of pieces of apparatus, rather than upon one or two, has been consistently carried out. If one or two switches fail, it is of small importance so far as service is concerned. If a whole primary feeder fails, (as, for instance, might be caused even in a loop system by a regulator short circuit), service will still be maintained.

For some time I have been indirectly in touch with the operation of several systems of this type and know of only two service outages which have occurred. In one of these cases short circuits occurred on both of the only two primary feeders which had then been installed. In the other case, the network was torn apart by the blowing of sectionalizing fuses. The conditions which permitted both of these outages to occur have been or are being corrected,—the first by the installation of additional feeders, and the second by the removal of the sectionalizing fuses. In other words, the service reliability of these systems, in so far as it is related to the full application of this network scheme, has been practically 100 per cent perfect.

The question raised by Mr. Hood concerning the safety to workmen when work is to be done on the high-tension conductors, and a feeder is killed for this purpose by the opening of a station switch, is answered by the fact that the energy necessary for closing each network switch is obtained from the transformer side of the low-voltage circuits. Therefore once the feeder has been killed, it is impossible for any one of the corresponding network switches to close of its own accord until the feeder has first been made alive again by manual operation. However, in order to guard against human errors, it is customary in most systems of this type to short circuit and ground the primary conductors at one or two different locations when work is to be done. Permanent facilities for doing this are provided at two or three points in each feeder, and the process is therefore no more difficult than clearing the circuit at two points in a loop feeder.

D. K. Blake: I am glad Mr. Milne called attention to the saturation. We do not get a strict measurement of power. But this is an advantage in connection with short circuits because the secondary current lags the primary current, which makes it safe. A highly leading cable charging current in reverse direction would be disadvantageous, but removal of the lag plate would keep it well within the tripping range.

I agree with Mr. Milne regarding the faults to ground and reclosing. I simply had in mind the conditions when a breaker failed to trip during a switching operation made for purposes of working on the feeder or saving the losses.

Mr. Forbes' statement is also true, but in the statement in my paper I had in mind that the reactances in the transformer were inherent; that is, some systems do have 10 per cent inherent reactance and the tripping characteristic must be kept above 84 deg.

RADIO BROADCAST COVERAGE OF CITY AREAS[1]

(Espenchied)

New York, N. Y., November 12, 1926

S. J. Zammataro: The statement was made that it is possible for the ratio of energy in the broadcasting of a symphony orchestra corresponding to the fortissimo and pianissimo parts to be one million to one. Is that provision made in the broadcasting station to control that ratio, and if so, to what extent is it controlled?

J. B. Taylor: This paper shows in a quantitative way what I think many observers must have appreciated in a qualitative way. Most radio fans give the impression that it is perfectly easy at any time to pick out almost any station they want, but I think it is also the experience of those not operating their own sets that when they ask someone else to pick out a particular station at a particular time, for one reason or another, it doesn't come.

This paper shows that the millions of potential listeners who we should like to think are keeping their ears glued to the receivers or sitting in front of the loud speaker enthralled at what is being put out, are a good deal of a myth; that while the audiences are large, tremendously large, compared with what can be placed in an auditorium, they are not, as a rule, in these large figures which are claimed. And this ought to lead to a reappraisal of the extent to which the broadcast message is going and to better engineering judgment in the placing of broadcasting stations, not only in locating one with respect to others, but also reappraisal of the economical size of stations. There shouldn't be a disproportion between the amount of money and energy put into the plant and the amount of program-making energy and artistry which fit into this plant.

If I may attempt to express an opinion on the question raised, "to what extent does the control of the symphony program follow or fail to follow the proper intensity of the music?" I should say that if the intensity of the music ranges from one million to one, (and I have no reason for suggesting anything else), and, as intimated in the paper, the attempt is to keep up with the music or ahead of it, or a little behind it, to the extent of ten thousand to one, perhaps that is the best we can do, but in a typical program perhaps from a good symphony orchestra with a chain of stations, how many operators or supervisors have it within their power to effect this change of intensity? Anywhere, you may be at the mercy of any number from one to six or seven or ten, not, perhaps, counting yourself as the last man in line or the man running the set to which you are listening, and how many of these people have the proper musical judgment to do this? In other words, the musical composer, the conductor, and the skilled musicians are doing their best to give you music with graded intensity, and another lot of men, skilled and trained but perhaps not skilled and trained in music, are doing their best to iron it out to a dead level.

G. T. Croker: I should like to ask if there is a relation between field intensity and distance?

K. B. Lyman: Mr Taylor pointed out that the control that was exercised on a broadcasting program is under the influence of a number of men. I believe that is not exactly the proper situation. The control is left more or less constant and the difference in energy levels between the maximum volume and the minimum volume is more a function of the ability of the loud speaker to reproduce it and of the noise levels introduced along the line, and that is of the order of ten thousand. If we can assume a reference level, a loud speaker will give 20 to 30 T U above that level, whereas the noise level will be perhaps 20 to 30 T U lower. The noise level will be lower than that, but the sum of noise might come up that far; so, actually, you would get a transmission in your radio system from a tone of about like a whisper to something somewhat louder than the speaking voice, without particular distortion.

R. W. King: Such a formula as Mr. Croker has in mind is, I believe, given in the paper (first column third page).

K. Sreenirasan (communicated after adjournment): The paper is of considerable interest to me, specially from one or two points. The survey that has been carried out cannot but be of great value in the choice of location for broadcast stations in places other than New York as well. The rapid growth of large cities with the enormous increase in the use of reinforced concrete buildings, reaching up to several hundred feet, creates a problem of radio broadcast distribution of considerable complexity.

The measurements of the author within such buildings forcibly impress on the mind the very pronounced shielding

1. A. I. E. E. Journal, January, 1927, p. 25.

effect of steel structure buildings. The figures, 83,900 $\mu v./m.$ on the roof with 858 $\mu v./m.$ on the ground floor, and 52,900 $\mu v./m.$ on the road with 858 $\mu v./m.$ inside the building at the same level as the road, are striking.

The author lays considerable stress on the necessity for increased power in the existing broadcast stations. On the other hand, there are some people who prefer a large number of low power stations to cater to local needs. Economic considerations favor a smaller number of high power stations. The disadvantages of such an arrangement are sufficiently clear. A field strength of 50,000 $\mu v./m.$, not to speak of any higher values, is so large that a receiver situated fairly close to the station and wishing to hear other stations would experience considerable trouble due to jamming, though the set may be highly selective. Secondly, as the author remarks, the field intensity increases relatively slowly with radiated power; the necessity arises, therefore, not so much for an increase of power in the station, as for another station of probably the same or less power. A value of 10,000 $\mu v./m.$ is about the right value for good quality reception without very expensive receiving apparatus. From this point of view, a few stations of 5 to 15 kw. seem to be better for a given area than one or two of 50 or 100 kw., taking the service range to be about 25 to 30 mi.

I am much struck with the field strength curve for WEAF. The intensity seems to remain practically constant after the first 80 mi. right away up to 240 mi. from the transmitter. I wish the author would give us the percentage departure from the theoretical values and carry on a fuller investigation into the curious departure from the normal decay curve.

With regard to the remarks of the author regarding selectivity of receivers, it seems as though reception will not improve by using highly selective receiving circuits. Taking the band of voice frequencies on either side of the radio frequency wave f_r to be about 10 kc., then, for good quality reception, the receiver should exhibit comparative flatness over the range $f_r - 10{,}000$ cycles to $f_r + 10{,}000$ cycles per second. Sharp cut off is not only desirable but essential below $f_r - 10{,}000$ and above $f_r + 10{,}000$. High selectivity within this band will necessarily mean disproportionate reproduction of the various received radio wave components; and this does not mean good quality reception. On the other hand, a fairly wide separation of the radio frequencies of various stations and the use of a moderate number of medium power stations will perhaps be a better solution.

THE INDUCTION LAMP, A NEW SOURCE OF VISIBLE AND ULTRA-VIOLET RADIATION[1]

(Foulke)

New York, N. Y., November 12, 1926

Saul Dushman: I am going to ask you to take your mind away from the purely material problems of lighting streets, railway yards, etc., and consider, with me, the production of light by the atom. Our present views on the production of light originated with a Danish physicist, Niels Bohr, in the year 1912. So much has been published and written about this theory that I am afraid I will be repeating a great deal of what is probably quite familiar to a number of you. Nevertheless, I am going to present a sort of bird's eye view of the theoretical side of the problem with which Mr. Foulke will deal from a practical side.

Our present views of the theory of light production rest essentially upon the conception of the atom as consisting of a positively charged nucleus surrounded by one or more electrons, the number of electrons being the same as the place of the element in the periodic table. Thus, hydrogen has a unit positive charge on the nucleus and one electron, helium has a charge of two positive units of electricity on the nucleus and two electrons, and so on. In the normal condition of an atom, these electrons are rotating in circular or elliptical orbits about the nucleus.

1. A. I. E. E. Journal, February, 1927, p. 139.

Now, let us assume that we have a number of hydrogen atoms in one of the two electrode vacuum tubes, with which everyone is familiar nowadays, and we gradually increase the voltage on the plate with respect to the filament from zero to higher values. An examination with a spectroscope would show that at a certain critical voltage, a single line is emitted and that as the voltage is increased, more and more lines appear until, finally, at a certain critical voltage, which is 13.5 volts in the case of hydrogen, we would obtain the complete spectrum of atomic hydrogen.

The explanation of the mechanism by which the spectrum is produced is as follows:

The electrons emitted from the cathode of the two electrode tube acquire kinetic energy as they move across to the anode. On collision with a hydrogen atom the electrons tend to impart this kinetic energy to the hydrogen atom and they do so if this energy is sufficient to knock the electron in the atom out from its normal orbit and lift it to another orbit which is located at a distance that is four times as great as the radius of the electronic orbit in the normal hydrogen atom. The hydrogen atom, which has collided with the electron, is said to be in an excited condition, and naturally the electron which is now rotating at a much greater distance from the nucleus tends to return to its normal condition. In doing so the same energy which was absorbed from the impinging electron is re-emitted as light of a definite frequency given by the relation

$$\nu = (E_1 - E_2)/h$$

where h is the so-called constant of the quantum theory and $E_1 - E_2$ is the difference in energies of excited and normal atoms, respectively. In the case of an atom like that of hydrogen, the electron can rotate in orbits which have radii whose values are $1, 2^2, 3^2, \ldots n^2$ times that of the electron in the normal orbit. To each of these orbits we can assign a certain amount of energy with respect to the electron in the normal orbit, that is, we can speak of this as the amount of energy required to lift the electron from the normal orbit to the outer one, and the energy required to do this is usually obtained from bombarding electrons, but may also be obtained by collision with high velocity atoms or by collision with other excited atoms. The atom in the excited state tends to return spontaneously to the normal condition and reemits the energy which has been absorbed previously, in the form of radiant energy. Corresponding to transitions from one energy level (or one orbit) to another energy level (or orbit) a monochromatic radiation is emitted whose frequency is given by the equation referred to above.

Of course the whole story is not quite so simple as this; not only do we have circular orbits, but also elliptical orbits as well, and there are certain relations governing the possible transitions that may occur between different classes of orbits. Also, there is an added complication in the case of elliptic orbits, which is due to the fact that the electron moves much more rapidly when it is close to the nucleus. As shown by the theory of relativity, there is an increase in mass of the electron as it approaches the velocity of light, and, therefore, instead of rotating in a closed elliptical orbit, the electron rotates in a precessing orbit. This leads to a fine structure of the spectrum lines.

This picture of the origin of spectral lines as due to the transition of an electron from one energy level in the atom to another is applicable not only to ordinary or visible spectra but also to the infra-red radiations on the one hand, and to ultra violet and x-rays on the other. It also explains a large number of interesting phenomena that occur in gaseous discharges, and has led to a number of new experiments in the past few years, all of which have given additional confirmation of Bohr's point of view.

Thus, the new theory accounts beautifully for certain resonance phenomena observed by Professor R. W. Wood in the case of mercury. As shown in Fig. 2 of Mr. Foulke's paper, the normal level of the valence electron in mercury is known as a 1 S level. If mercury atoms are bombarded by electrons having a velocity

corresponding to 4.9 volts, the valence electron in the mercury atom is raised to the level which is designated by spectroscopists as a 2 p level. As the electron then returns to its normal level, the line of wave length 2536 Angstrons is emitted. But the same line is also emitted if mercury in an evacuated quartz bulb is illuminated with light of this wave-length, and the explanation is evident from Bohr's theory. Now if in addition to this light, the mercury is also illuminated by light of wave length 3125, the valence electron is raised to a still higher level known as 3 d', and then it is possible to obtain the lines of wave lengths which correspond to transitions from the higher level to intermediate levels.

As mentioned previously, an atom A may be excited not only by collision with electrons, but also by collision with another atom which is in the excited condition. Thus if B in the excited condition has more energy available than is required to raise the electron in atom a to the next level, it is very probable that under certain favorable conditions, instead of obtaining the radiation which corresponds to the transition from the higher to lower level in B, this energy is transferred to A and the radiation actually emitted is that corresponding to the transition from higher to lower level in the latter atom. This is known as a collision of the second kind and the phenomenon is of great importance in determining the nature of the light emitted from mixed gases. Mr. Foulke's investigations as described in his paper give many illustrations of this phenomenon.

The whole field of spectroscopy has been completely revolutionized by Bohr's theory, and the influence of this theory on our conceptions of atomic structure has been profound. While a great deal of progress has been made in the development of Bohr's point of view, the whole subject is still in a state of flux and the future will undoubtedly bring forth even more striking conclusions regarding the nature of the electron itself and of the mechanism of the transitions between energy levels.

(In connection with this discussion, a model was shown of a precessing electronic orbit.)

Herman Goodman: Although not an engineer, it has been my good fortune to be associated with them as relates to my work as a physician interested in light in therapeutics. I heard of Mr. Foulke's work during the discussion of my paper on "Light in Medicine and Surgery", which I gave at Spring Lake before the Illuminating Engineering Sceiety.

I have been using high-frequency apparatus to excite a quartz tube, which contained a drop of mercury and some neon gas, in experiments in an attempt to get an emission of more or less unadulterated ultra violet. I have been limited in both the apparatus for excitation, and in the character of the tubes. The reason of the attempt was to get the effect of the ultra violet on the biology of the patient, and to simulate the good effects of the ordinary mercury vapor arc in quartz excited by the ordinary current.

By the high-frequency current mercury vapor bulb it should be possible to arrange an emission more controlled than at present. It is held for example, that a mercury vapor arc in quartz gives certain biological effects, but everyone knows that the ultra violet which comes from it is in conjunction with zones of visible light and of heat. This is very definite.

From the experiments done, it seems possible that ultimately we will have controlled emission of ultra violet in enough quantity to get effects on the patient. As mentioned, I have gone through some of this work in a crude way. I had no calorimeter nor photometer. It seems to me though, that from what I have seen here this morning that the ultra violet is strong enough to show its presence but that biologically there would be little effect at 3130.

C. H. Sharp: I want to say a word of appreciation for the wonderfully lucid, simple, and understandable explanation of the modern theory of the production of light by gases that Dr. Dushman has given us.

Mr. Foulke's paper pointed to some remarkably interesting experiments and experimental results. His demonstration of the effects which are produced was most interesting and I am sure that every one here feels very much indebted to him for having made it. Future experimental work along the lines on which Mr. Foulke is working should be of very great promise.

Selby Haar: Is Mr. Foulke's work just an experiment, or has it an immediate commercial aspect?

J. B. Taylor: Is this lamp an induction lamp or something else? Mr. Foulke in his synopsis says "the induction lamp, or, more generally speaking, the electrodeless electrical discharge." Now, is that more generally speaking, or more specifically speaking? It seems to me the latter is the true state of the case. That is only one of the many possible forms of induction lamps.

Also, what possible advantages do we gain by introducing the energy into the glass bulb by induction rather than conduction?

I submit that this lamp is a gaseous lamp more properly. The essence of what we have seen is the gaseous discharge either with or without electrodes. The essence of it is not induction which we have applied one state back in the great majority of all our incandescent lamps. The electrodeless feature is incidental and might be applied to incandescent or arc lamps if you are disposed to it. Incidentally, and to its disadvantage, it is a high-frequency lamp which calls for special apparatus.

If I might ask one specific question, in the calorimeter tests we measure losses not only in the bulb but presumably also in the inducing coil and that leads to the point when you are giving these figures on watts per candle, where should you begin and where should you end? Should we say the bulb is the lamp, or is the coil an essential part of the lamp, or the high-frequency apparatus back of it part of the lamp? It is feasible to determine the losses in the coil alone without the presence of the lamp, or the losses in the coil greatly modified by addition of the lamp, and is it easily feasible to make a separation?

O. H. Ovhler: I should like to know if anything is available concerning possible life of a gaseous container like that through a a period of hours of use and if there are any data to depend on covering total efficiency from input at 60-cycles measured in luminous output?

E. W. Beggs: Can you get a white light from a lamp of this type?

T. E. Foulke: The first point of interest is that brought up by Dr. Goodman is regard to the monochromatic character of the light obtained from the induction discharge. The method of producing spectra which was briefly outlined today, that is, by indirect excitation, has been applied to about thirty pure metals besides mercury. From some of these substances, we obtain strictly monochromatic light. A particular example is a mixture of Argon and phosphorous. The Argon is excited by the discharge and the spectra of phosphorous is obtained. There are two distinct bands of radiation. The first in the neighborhood of 7000 Å and the other at 2537 Å. The location of the emission lines observed in the various substances are sometimes found in the infra-red, others in the visible and still others in the ultra-violet region.

Mr. Selby Haar has asked a question regarding the commercial adaptations. Several fields of application have been considered but at this time it is too early to say what the outcome will be.

In regard to Mr. Taylor's last question concerning the calorimeter measurements, I feel quite safe in saying that the current circulating through the coil causes no appreciable loss under ordinary experimental conditions. This would most certainly not be the case if a small wire were used in construction of the coils.

In regard to Mr. O. H. Ovhler's question regarding the life and the over-all efficiency, in the early stages of the development, the life of these lamps was very erratic and by careful study of the conditions it was found necessary to use pure gas

in filling pure vacuum distilled mercury, and the container be baked at a temperature in excess of 400 deg. cent.; furthermore that a discharge should be run in the lamp, while disconnected from the vacuum system, before the final gas was admitted and sealed off when out of use. After these precautions were taken there was very little trouble with blackening, etc. Some of the lamps prepared in this manner were used intermittently for practically the period of a year without any apparent change. Over-all efficiencies were obtained ranging in the neighborhood from 15 lumens per watt to a value of approximately 40 lumens per watt.

In regard to Mr. E. W. Beggs question, I believe it is possible to very closely approximate daylight color. Each combination of gas and vapor gives a different tint or color and it is possible to obtain a variety of colors. It is possible that daylight color will best be obtained from metallic compounds. I must state, however, that no attempt has been made to determine whether or not we could produce daylight.

Discussion at Pacific Coast Convention

SYNCHRONIZING POWER IN SYNCHRONOUS MACHINES[1]

(PUTMAN)

SALT LAKE CITY, UTAH, SEPTEMBER 7, 1926

F. E. Terman: The results of Mr. Putman's carefully made calculations will be partially upset if the motor is fed by lines and transformers that have considerable impedance. This is because Mr. Putman's derivation assumes a constant voltage at the motor terminals, and this constant terminal voltage is not obtained if the supply lines and transformers have much impedance. In such a case the surging line current causes a varying voltage drop in the line. The effect of the line impedance can be taken into account in Mr. Putman's result by interpreting the motor terminal voltage to be the voltage nearest the motor that is substantially constant during the surging, and interpreting the so-called "real armature impedance" as the actual armature impedance plus the line and transformer impedance between the motor and the point of constant voltage.

Since the supply line characteristics are likely to be beyond the designer's control, the most carefully designed motor cannot be satisfactory under all conditions. It is the old story over again, to the effect that the performance of a piece of electrical apparatus cannot be obtained with 100 per cent accuracy without considering the characteristics of the network with which the apparatus is associated.

F. K. Brainard: A considerable part of Mr. Putman's paper is devoted to the apparent increase in synchronizing power of a synchronous machine as the frequency of the impulses increases. Mr. Putman calculates values of P_s corresponding to each harmonic in the tangential effort curve of mechanical power but unfortunately does not state just how he will use them in obtaining the electrical power pulsation.

Presumably he will use equations similar to those which he derived in his articles which appeared in the *Journal* of the Franklin Institute, May and June 1924. In the case of a single machine connected to an infinite system, these equations result from the solution of the following differential equation:

$$I \frac{d^2 \psi}{dt^2} + T_d \frac{d \psi}{dt} + G \psi = f(t) \tag{1}$$

where

ψ = Displacement angle.

I = Moment of inertia of the revolving parts.

T_d = Damping torque per mechanical radian per second change in displacement.

G = Torque per mechanical radian displacement.

$f(t)$ = Torque at the shaft.

This equation is the basis of all previously published work along this line so far as the writer knows, but it does not take account of damping correctly. In fact, the whole phenomena is somewhat more complicated than this equation indicates, and it has occurred to the writer that it may be the inaccuracy of the solution based on the above equation which causes the discrepancies which Mr. Putman has undoubtedly observed and which he has attempted to take into account by means of a P_s which varies with the frequency.

The trouble is that the damping torque is assumed proportional to $\frac{d\psi}{dt}$ which is the rate of change of the total displacement angle of the machine. It is quite obvious that this cannot be correct since all that the damping can possibly do is to prevent the shifting of the flux relative to the poles. It cannot by any possibility limit the displacement between internal and external voltages resulting from the impedance of the armature. In other words it acts on only a part rather than the whole of the displacement.

It seems to the writer that this part of Mr. Putman's paper is not quite correct especially if he uses the solution of Eq. (1) to compute power pulsations for the following reasons:

1. It involves taking account of damping twice since the effect of the induced currents in the field which Mr. Putman calculates is really damping to a considerable extent and T_d in Eq. (1) is also a damping factor.

2. As stated above Eq. (1) and anything resulting from its solution is incorrect.

It would seem much more logical and it is certainly much simpler to lump the entire effect of damping into one factor, which will include the effect of the induced currents in the entire field structure, and assume that the damping torque is proportional to the product of this factor (which we will call H) and the rate of change of the flux *relative to the poles.*

This leads to the following formulas from which the pulsations in electrical power can be computed if the analysis of the mechanical power curve is known.

$$Q_n = \sqrt{\frac{G_1^2 + (\omega_n H)^2}{\left[G_1 \Sigma \omega_n^2 I \left(1 + \frac{G_1}{G_2}\right)\right]^2 + \left[\omega_n H - \frac{\omega_n^3 H I}{G_2}\right]^2}} \tag{2}$$

(See derivation at end of discussion).

$$\gamma_n = \tan^{-1} \frac{\omega_n H \Sigma \frac{\omega_n^3 H I}{G_2}}{G_1 - \omega_n^2 I \left(1 + \frac{G_1}{G_2}\right)} - \tan^{-1} \frac{\omega_n H}{G_1} \tag{3}$$

where

Q_n = Ratio of electrical to mechanical power of the nth harmonic in the power curve.

G_1 = Torque per mechanical radian shift of flux across the poles.

G_2 = Torque per mechanical radian displacement between internal and external voltages.

H = Damping torque per mechanical radian per second shift of flux across the poles.

ω_n = 2 π times the frequency of the nth harmonic.

1. A. I. E. E. JOURNAL, December, 1926, p. 1229.

γ_n = Phase diff. between internal and external voltages.
I = Moment of inertia of revolving parts.

In order to compute G_1 and G_2 it is of course necessary to separate the displacement angle ψ into its two parts, *viz*: the displacement between internal and external voltages, and the displacement of the flux relative to the poles.

Perhaps the problem can be most easily understood by reference to the mechanical analogy of the forced oscillation of a weight suspended by a spring. A pulsating force P corresponding to the pulsation in torque required by the compressor results in pulsations in the reaction of the support P_1 which corresponds to the power drawn by the motor from the line. This is the case without damping.

The usual assumption concerning damping mentioned above is that the damping can be represented by a dash-pot in parallel with the entire spring as in Fig. 1 the damping force being proportional to the velocity of W. This leads to Eq. (1) above and is obviously incorrect since, as stated previously, the dampers act on only a part of the displacement.

A more accurate analogy is where the dash-pot is in parallel with the lower part of the spring only as in Fig. 2. The displacement of the upper part of the spring corresponds to the displacement between internal and external voltages while the displacement of the lower part corresponds to the displacement of flux relative to the poles and this later displacement is the part which the dampers restrict. Eq. (2) and (3) give the solution corresponding to this condition.

The apparent increase in synchronizing torque with the frequency of the pulsation can be readily understood from Fig. 2.

As the frequency increases, the displacement of the lower part of the spring decreases, the upper part taking more of the load

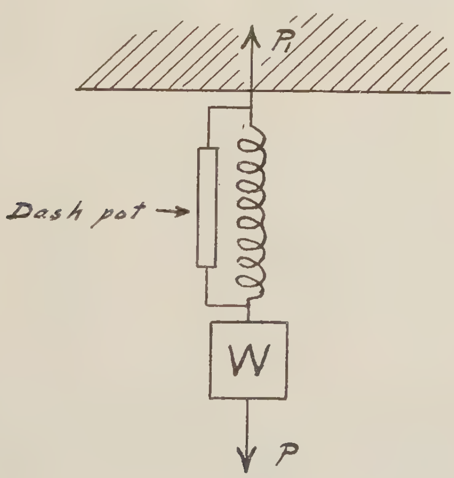


FIG. 1

and hence there is more load per unit total displacement than for low frequencies. If the frequency becomes very large, while the weight is reduced so that the accelerating forces remain finite, the deflection of the lower part of the spring becomes very small, practically the entire deflection occurring in the upper part of the spring.

This is shown by putting a $\omega_n H$ infinite in equation (2) which then becomes

$$Q_n = \frac{G_2}{G_2 - \omega_n^2 I}$$

This is the equation for undamped oscillations with resonance at $\omega = \sqrt{\frac{G_2}{I}}$.

If the damping is zero Eq. (3) becomes

$$Q_n = \frac{G}{G - \omega_n^2 I}$$

Resonance is now at $\omega = \sqrt{\frac{G}{I}}$.

In other words, as the damping or the frequency varies between zero and infinity, the synchronizing torque apparently changes from G to G_2.

This agrees in a general way with Mr. Putman's conclusions

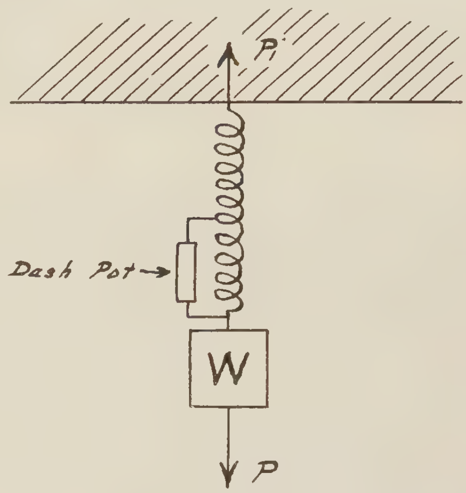


FIG. 2

and does not require the idea of a P_s which varies with the frequency.

The writer has found also that if T_d in Eq. (1) is calculated from the straight part of the speed—torque curve of the machine in question near synchronism, as mentioned by Mr. Putman in his Franklin Institute articles referred to above, the value of T_d is entirely too great to account for the pulsations observed in operation; but if this same value is used as H in Eq. (2) and (3), the observed results check the calculations much more accurately. The test data which the writer has covering this point are very meager, however, but seem to be correct.

The above method is not beyond criticism since the following assumptions are made which are not strictly correct:

1. The armature losses are neglected.
2. The total displacement, as well as the separate parts of the displacement, are assumed proportional to the torque under steady load over the range of load considered.
3. The direct magnetizing and demagnetizing effect of the current induced in the field winding, which Mr. Putman stresses, is taken account of only as it is included in the damping factor H.

The first and second assumptions are obviously approximations, but if suitable values of P_s, P_{s1} and P_{s2} are taken, the error from these sources is probably not large.

The error from the third assumption is probably not so very great, since the induced currents in the damper winding have a direct magnetizing or demagnetizing component as well as the current induced in the coils. In fact, the whole effect of the induced currents in both the dampers and the exciting winding on the field poles is to attempt to hold the flux constant in magnitude and fixed in position relative to the poles and so it seems that the error resulting from including the whole effect in the one factor H cannot be so very great.

The following is the derivation of Eqs. (2) and (3):

Let

T = Torque corresponding to mechanical power delivered by the motor which it is assumed can be expressed by a Fourier series of the form $f(t) = a_0 + \Sigma\ [a_n \cos(\omega_n t + \alpha_n)]$.

T_1 = Torque corresponding to the electrical power delivered to the motor which can also be expressed by a Fourier series of the form $f'(t) = b_0 + \Sigma\ [b_n \cos(\omega_n t + B_n)]$.

T_3 = Accelerating torque of revolving parts.

ψ_1 = Displacement of flux relative to the centers of the poles.

ψ_2 = Displacement between internal and external voltages.

$\psi = \psi_1 + \psi_2$ = Displacement of rotor relative to the terminal voltage.

G_1 = Torque per mechanical radian shift of flux across poles.

G_2 = Torque per mechanical radian displacement between internal and external voltages.

$G = \dfrac{1}{\dfrac{1}{G_1} + \dfrac{1}{G_2}}$ = Torque per mechanical radian displacement of rotor relative to terminal voltage.

H = Damping torque per mechanical radian per second shift of flux across the poles.

I = Moment of inertia of revolving parts.

ω_n = 2π times the frequency of the nth harmonic.

$q_n = \dfrac{b_n}{a_n}$

Then

$$T_1 = H\frac{d\psi_1}{dt} + G_1\psi_1 \qquad (4)$$

Since

$$T_1 = G_2\psi_2.\ \psi_2 = \frac{H}{G_2}\frac{d\psi_1}{dt} + \frac{G_1}{G_2}\psi_1$$

Then

$$\psi = \psi_1 + \psi_2 = \left(1 + \frac{G_1}{G_2}\right)\psi_1 + \frac{H}{G_2}\frac{d\psi_1}{dt}$$

Hence

$$\frac{d^2\psi}{dt^2} = \left(1 + \frac{G_1}{G_2}\right)\frac{d^2\psi_1}{dt^2} + \frac{H}{G_2}\frac{d^3\psi}{dt^3}$$

$$T_3 = -I\frac{d^2\psi}{dt^2} = -I\left(1 + \frac{G_1}{G_2}\right)\frac{d^2\psi_1}{dt^2} + \frac{HI}{G_2}\frac{d^3\psi_1}{dt^3}$$

But

$$T = T_1 - T_3$$

Hence

$$T = \frac{HI}{G_2}\frac{d^3\psi_1}{dt^3} + I\left(1 + \frac{G_1}{G_2}\right)\frac{d^2\psi_1}{dt^2} + H\frac{d\psi_1}{dt} + G_1\psi_1$$

Writing this in the operator form, we have

$$\left[\frac{HI}{G_2}p^3 + I\left(1 + \frac{G_1}{G_2}\right)p^2 + Hp + G_1\right]\psi_1 = f(t) \qquad (5)$$

Neglecting the transient, the solution for ψ_1 consists of a constant term corresponding to the average torque a_0 plus a variable part corresponding to the series $\Sigma\ [a_n \cos(\omega_n + \alpha_n)]$. The second part represents the hunting due to the harmonics in $f(t)$. Only the second part is of interest since this determines the power pulsations. The transient part of the solution is obtained by letting the right hand member of Eq. (5) = 0 and solving for ψ_1, but this represents oscillations which occur for a short time only after the machine is parallel with the system and so do not interest us.

The permanent hunting is easily obtained by letting $p = j\omega_n$ n, being the order of the harmonic in $f(t)$.

Eq. (5) then gives

$$a_n = \left\{G_1 - \omega_n^2 I\left(1 + \frac{G_1}{G_2}\right)\right\} + j\left\{\omega_n H - \frac{\omega_n^3 HI}{G_2}\right\}$$

or in real quantities

$$a_n = \sqrt{\left\{G_1 - \omega_n^2 I\left(1 + \frac{G_1}{G_2}\right)\right\}^2 + \left\{\omega_n H - \frac{\omega_n^3 HI}{G_2}\right\}^2}$$

Similarly from (4)

$$b_n = \sqrt{G_1^2 + (\omega_n H)^2}$$

Dividing (5) by (4) we have

$$Q_n = \sqrt{\frac{G_1^2 + (\omega_n H)^2}{\left\{G_1 - \omega_n^2 I\left(1 + \frac{G_1}{G_2}\right)\right\}^2 + \left\{\omega_n H - \frac{\omega_n^3 HI}{G_2}\right\}^2}} \qquad (2)$$

The phase lag of b_n with respect to a_n will be the difference between their phase angles, and is

$$\gamma_n = \tan^{-1}\frac{\omega_n H - \dfrac{\omega_n^3 HI}{G_2}}{G_1 - \omega_n^2 I\left(1 + \dfrac{G_1}{G_2}\right)} - \tan^{-1}\frac{\omega_n H}{G_1} \qquad (3)$$

C. A. Nickle: Some of the assumptions in this paper are sufficiently in error to affect seriously the correctness of the results. The first part of Section II of this paper deals with this problem and the results are in accord with those presented in a paper[2] by R. E. Doherty and the writer. Our treatment of salient-pole machines under transient conditions, however, does not agree with the treatment just presented.

Equation (34), according to the author, is the general equation for power for sustained oscillations. This is not justified because it applies only when x_e is a pure reactance, since this was the assumption under which it was derived. But x_e is not a pure

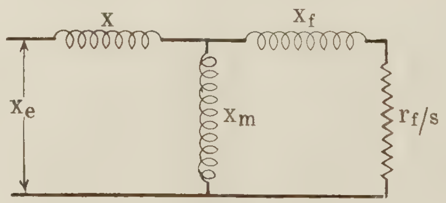


Fig. 3

reactance for all conditions of oscillation. It approximates a pure reactance when the resistance of the field winding is either negligible or infinite with respect to its leakage reactance at the oscillation frequency, as may be seen from the equivalent transformer diagram shown in Fig. 3 herewith. In this diagram, x is the armature leakage reactance, x_m is the mutual reactance of the field and armature, x_f is the leakage reactance of the field winding, and r_f/s is the field resistance referred to the armature for a frequency of oscillation s times the electrical frequency of the machine.

Inspection of Fig. 3 shows that as s approaches zero—*i. e.*, as steady-state conditions are approached—r_f/s approaches infinity and the field winding is essentially open-circuited. The impedance is then a pure reactance of value $(x + x_m)$ —*i. e.*, the synchronous reactance in the direct axis. As s becomes larger, r_f/s becomes smaller and may become quite negligible even for rather low values of s. As r_f/s approaches zero, the impedance of Fig. 3 again becomes a pure reactance. It is evident, however,

2. *Synchronous Machines*—I, by R. E. Doherty and C. A. Nickle, A. I. E. E. Journal, October 1926, p. 974.

that x_e is not the leakage reactance of the armature as concluded by the author, but is the transient reactance, which may be considerably greater in salient-pole machines.

This may also be interpreted as follows: When a three-phase system of currents of constant amplitude flows in the winding of a three-phase machine, there exists a uniformly rotating sinusoidal m. m. f. of constant amplitude. This m. m. f. rotates at synchronous speed, which is the speed at which the poles are rotating, and by proper time phase of the currents, a at zero power factor, the rotating m. m. f. may be made to exist at every instant directly over the field poles. If each of the three-phase currents pulsates in amplitude at a frequency f, the m. m. f. over the field winding will likewise pulsate at the same frequency. This pulsating m. m. f., acting over the field winding short-circuited through the exciter armature, will induce currents in this winding and we have essentially a transformer with the secondary short-circuited[3]. The magnetic and electric circuits of such a transformer are shown in Fig. 4. In this figure, p_1 is the permeance of the leakage paths of the armature, p_2 is the permeance of the mutual flux path of the field and armature, and p_3 is the permeance of the leakage paths of the field winding. The alternating component of armature m. m. f. is now represented by an alternating current in the winding a, the frequency of this current being the same as the frequency of pulsation of armature m. m. f. in the actual machine. If this frequency is infinitely small, the armature m. m. f. may send flux through the permeance p_1,

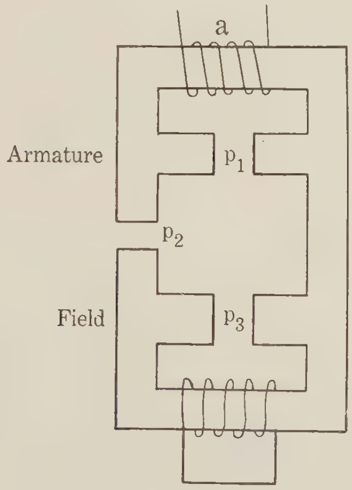


FIG. 4

which corresponds to the permeance of the leakage paths of the armature, and through the permeance p_2, which is the permeance of the mutual path of the armature and field. At this lower limit of frequency, due to the field resistance, flux can be created and destroyed in the field winding without opposition. Negligible flux passes through the field leakage path under this condition, since it is shunted by a path entirely of iron of relatively very great permeance. The reactance of the armature winding is then evidently the synchronous reactance. When, however, the frequency of the current in winding a is high enough so that the resistance of the field winding is negligible with respect to its leakage reactance, the short-circuited field winding effectively prevents any change of flux linking its self. In this case, the permeance encountered by the armature m. m. f. is not only p_1, the true leakage permeance, but also the permeance p_2 and p_3 in series. The total armature flux is correspondingly greater than just the armature leakage flux and the effective reactance is likewise greater than the armature leakage reactance in the same proportion. This reactance, as distinguished from armature leakage reactance, is termed transient reactance. In commercial salient-pole machines, the transient reactance is of the order of 50 per cent higher than the leakage reactance, and the effect of field leakage cannot be neglected as has been done by the author. Thus, the fact that the alternating component of flux linking the field winding is zero does not mean that armature reaction is entirely ineffective as stated in this paper on the fifth page in the second paragraph. The flux linking the field winding is, therefore, not a correct measure of the effectiveness of armature reaction, and hence the author's expression for the factor K' is invalid.

There is still another point in the calculation of K' which is in error. In deriving the expression for K', the author neglects such time-phase relations which occur, and since this problem differs from the problem of steady-state conditions only in the time element, this is altogether unjustifiable. When the time element is taken into account, the element of damping which exists is readily obtained, as well as a more accurate value of synchronizing power. When the frequency of oscillation is such that the field resistance is neither negligible nor infinite with respect to the field leakage reactance, x_e is not a pure reactance, but an impedance, and Eq. (**34**) does not apply.

In Eq. (**38**), $(N\ K\ \phi\ \omega\ \cos\ \omega\ t)$ is the alternating voltage induced in the short-circuited field winding. This voltage is consumed by the resistance and leakage reactance of the winding. On the sixth page, immediately below Eq. (**47**), the method outlined for obtaining L/r is in error, in that it gives the ratio of *exciting* inductance to resistance, which may be several times greater than the proper ratio of *leakage* inductance to resistance. Also, such a method does not take the amortisseur winding into account correctly, for the following reasons: The amortisseur winding is a short-circuited secondary with respect to the field coils, and the equation of the growth of field current when a constant voltage is applied is of the well-known form:

$$i = A + A_1 e^{D_1 t} + A_2 e^{D_2 t}$$

where

$$D_1 = \frac{-(r_1 L_2 + r_2 L_1) + \sqrt{(r_1 L_2 - r_2 L_1)^2 + 4 M^2 r_1 r_2}}{2 (L_1 L_2 - M^2)} \quad (1)$$

and

$$D_2 = \frac{-(r_1 L_2 + r_2 L_1) - \sqrt{(r_1 L_2 - r_2 L_1)^2 + 4 M^2 r_1 r_2}}{2 (L_1 L_2 - M^2)} \quad (2)$$

The equation for the field current thus comprises a constant term and two exponential curves, and an oscillogram taken under these conditions cannot be analyzed correctly as a single exponential curve. When the resistance of the secondary is relatively great, D_2 becomes very large and one of the exponential curves in a very short time becomes negligible. The curve then continues as a single exponential, but the value of L/r obtained from this part of the curve is not the correct value to use for the condition where a definite sinusoidal voltage is applied to the field winding.

In the third part of the paper[4], on *Synchronous Machines*, by R. E. Doherty and the writer, our treatment of the present problem is given. When the problem is analyzed with due consideration to the points brought out in this discussion, the expression for synchronizing power becomes:

3. When a machine is oscillating, it delivers or consumes power and a pulsating armature m. m. f. also exists over the quadrature axis. There is, in general, no field winding in this axis, and the flux is always proportional to the current. The reactance in this axis will thus be constant regardless of the frequency of oscillation of the machine—*i. e.*, it will always be x_s'. Although there is no field winding in this axis, there may be an amortisseur winding which acts as a short-circuited secondary. It may, however, be shown that in general the resistance of this winding compared to its leakage reactance is so great at ordinary frequencies of oscillation as to have a negligible influence on the quadrature reactance.

4. *Synchronous Machines*—III, A. I. E. E. Winter Convention, 1927.

$$P = P_1 + \frac{a\,(x_s - a) - b^2}{x_s\,[b^2 + (x_s - a)^2]}\; E_0^2 \sin^2 \psi_1 \tag{3}$$

where P_1 is the synchronizing power under steady-state conditions, ψ_1 is the angular displacement corresponding to the average load, and the factors a and b are functions of the oscillation frequency and may be readily obtained from the constants of the machine. The damping torque per radian per second is also obtained, and is given by:

$$T_d = \frac{b^2\, E_0^2 \sin^2 \psi_1}{s\,[b^2 + (x_s - a)^2]} \tag{4}$$

H. V. Putman: Dr. Terman has pointed out that these calculations assume constant terminal voltage at the machine and if this condition is not fulfilled, the synchronizing power is likely to be very different. This is a point which it is well to remember. I had an interesting experience which illustrates this point clearly. A certain synchronous motor had been directly connected to a particular air compressor. Severe hunting was reported and difficulty was experienced in keeping the motor in step. Investigation showed that the motor was supplied by a diesel-engine-driven generator about 50 per cent larger than the motor. This engine did not have nearly as large a flywheel as it should have had for direct connection to the generator.

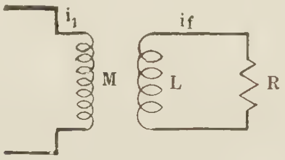


Fig. 5

Tests showed a current pulsation of about 175 per cent, based on the rated motor current. The pulsation consisted largely of two harmonics, one due to the compressor and the other to the engine.

Calculations showed that to bring the current pulsation down to 60 per cent, five times as much flywheel effect was required on the engine and about twice as much on the motor. It was impossible to add this amount of flywheel effect to the engine, so the trouble was remedied by substituting an induction motor in place of the synchronous motor.

It is not likely a condition as bad as this could occur due to poor regulation of transformers. Such an experience does, however, make one realize that synchronous machines which by themselves may behave quite properly often behave very badly when connected together or to a system having poor regulation.

Mr. Nickle says that my "effective reactance x_e " is not a pure reactance as I assume. Later he says "however, it is evident that x_e is not the leakage reactance of the armature as concluded by the author, but is the transient reactance which may be considerably greater in salient-pole machines." The term "transient reactance" has been clearly defined by Mr. Doherty and other writers and it is always treated as a pure reactance, so that if my x_e is in reality the transient reactance (which I think it is not) as Mr. Nickle says, then it is at least a pure reactance. Also I did not say that x_e is the leakage reactance of the armature; I said it is the leakage reactance of the armature plus that part of the de-magnetizing armature reactance which is effective under the oscillatory conditions.

I am not sure that the equivalent diagram Mr. Nickle gives in his Fig. 3 really represents the present problem. Certainly the field and armature circuits are not directly connected in series. They are only magnetically coupled as shown in my Fig. 5 (this discussion). Before one can justify conclusions based on Mr. Nickle's equivalent circuit is necessary to prove its equivalence.

Mr. Nickle states that the alternating voltage induced in the short-circuited field winding is consumed by the resistance and leakage reactance of the field winding. I say in the paper that this voltage induced in the field winding is consumed by the resistance and *self* induction of the field winding. This is an important point as it will make a difference in the value of K'. The point can be demonstrated quite easily by referring to my Fig. 5. In this figure the pulsating current which flows through the armature circuit is represented by i_1. Note that this pulsating armature current flows by virtue of the fact that the com-pressor to which the motor is connected demands certain pulsating power to drive it. There is only one power line coming into the motor and if the motor is to supply the power required to drive the pulsating compressor load, current must flow through the power line into the motor armature winding. If it does not the motor will stop. Hence, it is evident that this pulsating armature current flows regardless of what goes on in the motor and *this pulsating current is in no way limited or restricted by any of the reactions or reactances within the machine.* It flows because the compressor load demands it.

This problem is entirely different from the generator short-circuit problem. There the armature current does depend on what goes on inside the machine; in fact it is limited by the combined leakage reactance of armature and field which is the transient reactance, and this is the problem to which Mr. Nickle's diagram is applicable. In Fig. 5,

Let

L = the self inductance of the field winding.

R = The resistance of the field.

M = The mutual induction between field and armature.

Now, by Kirchoff's law, let us write the fundamental differential equation of the field circuit. It is obviously

$$0 = i_f\,(R + p\,L) - M\,p\,i_1$$

where

$$p = \frac{d}{dt}$$

The induced voltage produced by the armature current is the term $M\;p\;i_1$ and the field current is:

$$i_f = \frac{M\,p\,i_1}{R + p\,L}$$

so that it is easily seen that the pulsating component of the field current is equal to the induced voltage divided by an impedance comprised of the field resistance and the field self inductance, not the leakage inductance. The field leakage inductance would be

$$(L - M)$$

so that if Mr. Nickle were right, the equation would have to read:

$$i_f = \frac{M\,p\,i_1}{\gamma + p\,(L - M)}$$

which is impossible.

Mr. Nickle also says my calculation of k' is further in error because I have neglected certain time elements which occur, and when these are properly taken into account, it is possible to obtain the damping torque as well as the synchronizing torque. This is not clear to me, but if it is possible to obtain some sort of an expression for the complete torque, (probably a vector expression), one term of which is synchronizing torque and the other damping torque, it would be highly desirable. I shall be very much interested in seeing how Mr. Nickle handles this part of the problem.

Mr. Brainard has submitted a very interesting discussion, explaining why he thinks the synchronizing torque changes with the frequency of the load pulsations. He believes that if the damping is taken into account, properly, in the fundamental equation of the oscillation, this "apparent" change in synchronizing torque is explained without "the idea of a P_s which varies with the frequency."

The equation to which Mr. Brainard refers is $(p^2 I + p\, T_d + T_s)\, \psi = f\,(t)$. This is his equation (1) except that T_s is used for synchronizing power instead of G. This equation not only has formed the basis of all previous published work along this line, but it has been used successfully for many years in handling problems of oscillation and resonance. Also, many actual comparisons have been made between oscillations calculated from this equation and oscillographic tests which have substantiated, beyond any doubt, its validity within its well-known limitations.

It can be applied to ordinary synchronous machines which, as a rule, have a damping torque of from ½ to 1 per cent of the synchronizing torque. Cases of moderate oscillation can be calculated successfully from it and the magnitude of the oscillation obtained correctly. The shape of the oscillation usually departs somewhat from the oscillographic picture due to the fact that the linear type of differential equation does not apply strictly to the problem. The synchronizing torque is not absolutely proportional to the displacement except for small displacements and the damping torque is not proportional to the rate of change in displacement (either the total displacement or that part of it between the pole and the electrical field) except for very small values of slip. This means that, for a case of very severe oscillation where the magnitude of the oscillation depends to a large extent on the damping, this equation cannot be applied successfully. It will not give the magnitude of the oscillation correctly, but it will at least show if it is very severe and usually this is sufficient. If the oscillation is of such magnitude that it is

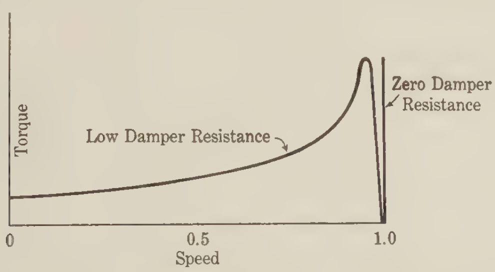


Fig. 6—Diagram Showing How the Speed-Torque Curve of a Motor with Low Damper Resistance Approaches a Straight Line of Finite Height as the Damper Resistance Approaches Zero

not objectionable for continued operation, then the magnitude can be calculated very closely.

It should be noted that both these limitations are present in Mr. Brainard's more complicated equation. I say "more complicated" because he is forced to a third-degree equation and has to employ two different values of synchronizing torque. And what is gained by the use of this complicated equation? Nothing, except that the damping torque is made to depend on, (I shall not say proportional to), that part of the displacement between the poles and the electrical field. This is as it should be, but when the proportionality is of such a questionable nature and the whole term is so small anyway, the use of the more complicated equation seems hardly justified.

Also, the value of resonance $\omega = \sqrt{\dfrac{G_2}{I}}$, which Mr. Brainard obtains from his equation for the case of infinite damping, has no physical significance. What does infinite damping mean? As Mr. Brainard uses it, it means that the motor develops an infinite torque with an infinitely small slip. This is not only an impossible condition, but it is a condition which cannot even be approached by an actual motor. Even though a motor were made with a damper winding resistance of very small value,—say approaching zero,—the speed-torque curve would approach a vertical line of finite length, not infinite length as Mr. Brainard assumes. (See Fig. 6.) This means that the linear relation between damping torque and slip fails long before anything approaching infinite damping could be obtained, so Mr. Brainard's explanation of a synchronizing torque which apparently changes from G to $G2$, falls through.

I feel very certain that if it is possible to obtain an expression for the complete torque of the motor, including both the damping torque and the synchronizing torque, it will be found that the term representing the synchronizing torque, varies with the frequency of the pulsations in a manner independent of the damping torque. Mr. Nickle has suggested the possibility of obtaining such an expression and I hope he will be able to demonstrate this point.

Mr. Brainard says I take damping into account twice, since the effect of the induced currents in the field which I calculate is really damping. I think he does not understand my point of view clearly. When the load increases suddenly on a motor and the angular displacement increases, there are really two voltages induced in the rotor winding, one due entirely to the transformer action between rotor and stator, brought on by the sudden increase in armature current, and the other, a voltage of rotation due to the rotor actually cutting the flux from the stator during the increase in the angular displacement. The effect of the latter voltage is pure damping, while the effect of the former is an increase in the synchronizing power.

Discussion at Winter Convention

MEASUREMENT OF TELEGRAPH TRANSMISSION[1]

(Nyquist, Shanck and Cory)

New York, N. Y., February 11, 1927

J. H. Bell: The old method of evaluating the quality of telegraph signals was by running a tape at a particular speed and measuring each dot and each space and comparing with the length of a perfect dot. That required a good deal of time to carry out. The experimenter in the laboratory, after making each change in his circuit, had to measure his tape before he could proceed any further.

With these newer tools we can change a coil or a relay and at the same time listen to the effect upon the circuit, so that the tools make for much quicker development work than hitherto.

The telegraph circuits in this country have a great many repeaters, and, as you will find in the paper, the maximum allowable distortion between terminals is 35 per cent. That does not mean that 35 per cent is an allowable distortion in one section. The distortion is cumulative from section to section, so that the permissible distortion in one section must be kept down to say, 4 or 5 per cent.

The old method did not permit of measuring 5 per cent distortion with any degree of accuracy, as pointed out in the paper; about plus or minus 3 per cent was the best that could be done. That was due to the variations in the speed of the tape running through the Wheatstone receiver.

In the older days when the Wheatstone was the system for carrying heavy traffic, it was perfectly satisfactory if one got all the dots, and was able to distinguish between the dots and the dashes; the human factor could then come in and make up the discrepancy and translate the tape without any difficulties.

However, today with the growth of machine telegraphs, it is necessary that the amount of distortion be kept down to a definite limit, and these new tools will certainly be a great aid in carrying out our experiments. Even in hand-operated systems, I question whether any operator can detect a few per cent distortion.

H. W. Drake: A rather significant statement is made on the first page of this paper, which leads me to ask a question. The statement I refer to is that "in the case of some printer circuits,

1. A. I. E. E. Journal, March, 1927, p. 231.

variation in lag degrades transmission. Consideration of lag is usually not of importance, however."

The question I wanted to ask is whether these admirable means which have been devised in the Bell System for measuring transmission include the possible measurement of this variation in lag.

The reason for asking that question is the fact that I am aware of a good deal of work that is being done by the commercial telegraph companies, and this matter of determining variation of lag has been one of the important factors in that work. I think that I would not be stretching the case to say that this paper is probably in the nature of a progress report and that the authors would be the last to have it taken as the final statement of what can and must be done in the measurement of telegraph transmission.

H. Nyquist: We have successfully used both the synchronous distortion bridge arrangement shown in Fig. 2 and the Wheatstone recorder in the measurement of lag and its variation. The field type of measuring set is not readily adaptable to this kind of measurement.

ILLUMINATION ITEMS

By Committee on Production and Application of Light

ARTIFICIAL LIGHTING IN FOUNDRIES

It is doubtful whether in this country more than one foundry out of six obtains all the benefit that it should from artificial light. The efficiency with which many foundry operations are carried on depends to a large degree upon the workers ability to see accurately and rapidly and in semi-darkness it is impossible for him to do either. Production and quality suffer from the effects of poor lighting and the accident risk is increased when vision is rendered difficult and uncertain.

Reliance cannot be placed upon daylight. Even under the best conditions there are some locations that are practically always in need of artificial light, (frequently the entire plant requires such supplementary illumination), and without it, night operation would of course be impossible. Where good daylight is obtained, the illumination will be 20, 50, or even more, foot-candles, but when artificial light is depended upon, the illumination is likely to be not more than one or two foot-candles and the value of this low illumination is likely to be reduced by glaring sources which interfere with vision and render seeing difficult.

The amount of light that should be provided for any operation should be sufficient to permit the work to be done quickly, with precision and accuracy. Experience has indicated that the illumination for certain operations should be not less than values as shown below.

RECOMMENDED ILLUMINATION

Class of work	Foot-candles
Charging furnaces	5
Floor molding and core making	6
Bench molding and core making	10
Casting, shaking out	5
Cleaning, chipping, tumbling	5
Annealing	5
Raw stock storage	1.5
Pattern storage	3

(Abstract of a paper by W. H. Rademacher, Edison Lamp Works, of General Electric Co., Harrison, N. J., presented before National Founders Association, Nov. 17, 1926.)

It is not enough, however, to provide sufficient illumination. It is of the utmost importance that glaring lights be kept out of the field of vision of the workman. A workman after looking at a glaring source is temporarily blinded, and there is a more than normal chance of his being accidentally injured or of his making some serious mistake until his vision recovers from the shock. Glare, even in its lesser forms, induces eyestrain and is a constant menace to safety. The use of bare lamps should be avoided.

Experience has proved that in such service steel reflectors having a porcelain enameled reflecting surface are usually most satisfactory, while in some cases prismatic or mirrored glass units are well adapted. Such equipment is impervious to the action of corrosive fumes which arise from certain processes. Equipment having aluminum or paint finished reflecting surfaces is unsatisfactory due to its rapid discoloration and depreciation. The dome-type porcelain enameled reflector provides a good spread of light and cuts off the direct rays from the lamp filament so that the source cannot be seen from ordinary positions.

The prismatic and mirrored glass reflectors find usage where units must be mounted very high, and where a concentrated distribution of light is desirable.

For very low mounting, the deep-bowl porcelain enameled reflector is advisable because of the sharper cutoff and better eye protection which it affords.

These units should be mounted overhead, arranged symmetrically to produce uniform illumination over the entire area in which work is done. The dark spots, glaring sources, harsh shadows and eye-tiring contrasts in brightness which are found in the old drop-cord method of lighting are thus eliminated.

The overhead or general lighting system is more economical in its operation than the local or drop-cord installation. In only a few exceptional cases local lighting may have to be used and then only to supplement general lighting where the character of the work makes it imperative, as in inspecting molds which are very deep and narrow. In such cases a 25-watt lamp should be used in a small deep-bowl steel reflector which will direct the light toward the work and keep it out of the workman's eyes. The armored type of conductor should be employed where cords are dragged about the floor, and a reeling type extension can be used to advantage. An incandescent lamp (known as the *rough service* Mazda lamp) and is well adapted to this portable service.

The smoky, dusty atmosphere of most foundries makes the question of the maintenance of lighting equipment particuarly important. The modern foundry, with its improved ventilating system, can keep its interior cleaner and brighter than was previously possible. This relieves the depressing effect of a dark and gloomy room and makes it much easier to light. The lamps and reflectors should be cleaned at intervals of about four weeks.

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Regional Meeting of Southwestern District Held in Kansas City

The Southwestern District of the Institute has every reason to be proud of its first Regional Meeting, which was held in Kansas City on March 17-18 with headquarters at the Kansas City Athletic Club. Approximately 225 members and guests attended the meeting. The technical sessions were well attended and drew forth excellent discussion, while the social features were particularly enjoyable.

While the technical sessions were going on, the ladies present were enjoying trips around Kansas City, luncheons, teas, a theatre party, etc.

Trips could be made by any of those attending the Convention at practically any time they desired, while on Saturday morning a number of trips were definitely scheduled for visits to various plants and power stations and residential sections in the city.

A conference of Branch Counselors and Students was held in connection with the meeting on Wednesday, March 16.

Banquet on Thursday Evening

The principal social event of the meeting was the banquet which was held in the Kansas City Athletic Club on Thursday evening, March 17. A. E. Bettis, as chairman of the meeting, introduced the toastmaster of the evening, W. J. Squire. A delightful dinner was served and this was followed by group singing under the direction of Herman Henrici. Then the principal speaker of the evening was introduced, J. W. Hudson, Ph. D., University of Missouri, who talked on the subject, "Contradictions of Today's World." Dr. Hudson gave a most entertaining and most instructive talk dealing particularly with the idealist and the practical thinker, and showing how the efforts of these two should and could be coordinated. Music was contributed during the dinner and afterwards for dancing by the orchestra of the Kansas City Power & Light Company.

Luncheon With Electric Club

On Friday at noon the members attending the meeting were guests at a luncheon given by the Kansas City Electric Club. Those who attended this luncheon enjoyed a talk given by Brigadier-General E. L. King, of Fort Leavenworth, on the subject of "The Causes of War."

Dinner at Northeast Station

On Friday evening a trip was made to the Northeast Station of the Kansas City Power & Light Company, where a buffet dinner was served, and this was followed by an inspection trip through the various parts of the Station.

THE TECHNICAL SESSIONS

Thursday Morning

A. E. Bettis, Vice-President of the Institute in the Southwestern District, opened the meeting on Thursday morning, March 17 with a short speech of welcome and then introduced G. S. Morris, chairman of the local Speakers and Technical Meetings Committee. After some announcements, Mr. Morris in turn introduced S. M. DeCamp, Secretary of the Kansas City Section, who presided during the remainder of the session.

The first paper on the program, entitled *Current Analysis in Circuits Containing a Resistance Modulator* was read in abstract by L. S. Grandy. R. M. Kerchner, in discussing this paper, stated that he did not agree that distortion is due to the non-linear pressure-resistance characteristic of the transmitter. He showed that if the pressure-resistance curve is a rectangular hyperbola, the output would be undistorted, neglecting resistance in the external circuit. He suggested that less distortion would be experienced with a transmitter that varies the e. m. f., as for instance, the magneto-type instrument.

This paper was followed by a second paper, *Development of Railway Signaling*, by T. S. Stevens. He gave a brief history of the development of railway signals from the first systems used to the latest systems, in which the signals are entirely in the engine cab. The system he described gives three speed indications, full speed, medium speed, and low speed. It is operated by alternating currents flowing in the rails, which act inductively on a sensitive receiving system having a detector located underneath the engine. This system not only gives an indication to the engineer but also operates valves which regulate the speed of the locomotive in case the engineer fails to do this.

The discussion on this paper by F. E. Snell pointed out that the development of the a-c. relays had made possible this system. He called attention also to the development in electric lamps which now allows a 10-volt, 16-watt bulb to be used where formerly a 100-watt lamp was required. He furthermore mentioned the advantages of the cab system for use in districts where the roadside signals are liable to destruction by boys, etc.

O. S. Major, in discussing this paper, gave the opinion that the old types of signaling would not be entirely dispensed with, as for certain conditions they were valuable. The electro-pneumatic type, he said, is quite desirable where very quick operation is demanded. He emphasized the fact that the automatic signals operate a closed circuit, and an accidental break causes the greatest restrictions in speed, thus making for safety.

He mentioned also the recent development of an automatic inter-locking system which is being satisfactorily applied for crossing protection.

W. H. Horsch told of a new type of rectifier which is well adapted for railway signal purposes. In this rectifier there are

no moving parts nor liquids and it can be built for any current or voltage rating.

Alfred Herz cautioned against the very grave danger of the accidental application of clear signals caused by disturbances on power lines adjacent to the railroad tracks. Experiments have definitely shown, he stated, that absolutely false clear signals can be received on the locomotive under certain conditions of current on the power lines. He suggested that the railroad signals should be made to operate at some other frequency than the 60-cycle frequency used by power lines, as this would probably eliminate the interference. He stated that some of the railroads are now using 100 cycles for their signals.

Chester Lichtenberg corroborated this and said that practically all of the 60-cycle signal systems had been discontinued for 100-cycle operation.

Mr. Stevens, in discussing this point, said that the effects of different frequencies are not thoroughly known at the present time, but that the problem is being worked out and experiments made with various frequencies as well as with preventive devices for operations at 60 cycles. He added that a-c. relays for the automatic block system will operate satisfactorily on a-c. railroads as well as on d-c. railroads by using a frequency different from the power frequency.

Automatic Substations Session

The Thursday afternoon session, at which R. L. Frisby presided, was on the general subject of automatic substations. Three papers were presented as follows:

A 21,000 Kv-A. Automatic Substation, by D. W. Ellyson,

Inspection, Maintenance and Test of Automatic Substation Equipment, by Chester Lichtenberg,

Carrier-Current Selector Supervisory Equipment, by C. E. Stewart and C. F. Whitney.

In discussing these papers, C. Antonio, who has had charge of automatic substations for the last ten years, said that daily inspection is not necessary and that he has been trying a system of casual inspections every two days, combined with a thorough inspection once per month. This system seems to be working out very satisfactorily. A new station, he said, should be checked daily until all the faults of installation have been corrected, and then the longer periods of inspection are sufficient.

He mentioned that he has operated one 500-kw. station since 1917 and out of about 145,000 operations there have been 1.1 failures per thousand operations.

He cautioned, also, against the supposition that all troubles can be prevented automatically, mentioning a case of a bearing thermostat, which, in cold weather, had operated too slowly to prevent the bearing from being damaged.

R. H. Millan, in commenting on Mr. Ellyson's paper, said that the bus-splitting scheme could be justified in an old station which had been re-designed for automatic operation but not in a new station. He commended the plan of not attempting to save the load when a transformer is lost and said, in fact, that his company is content to lose all of a small substation for a short period of 10 to 15 seconds in preference to installing the necessary costly protective apparatus which would prevent this.

He said that his transformers are usually operated self-cooled and water cooling is resorted to when the transformers are forced to carry overloads in emergencies. He gave some very interesting figures on the operation of four d-c. stations containing 6 units of converters and motor generators. Within one year there have been altogether 165 failures in these stations, totaling 337 machine-hours or 24 machine-hours per year for each 1000 kw. capacity.

These included all failures, many of which were not at all serious and 85 of the failures were discovered by inspectors before an outage occurred. Of these failures, 135 were attributed to failure of devices in the station, including 31 to d-c. circuit breakers. 30 of the failures were called human failures, of which 5 were attributed to carelessness, 5 to improper adjustment, and 5 to factory inspection.

About 3800 hours of inspection were put on the equipment and this work was done by a tester and a helper who visited the station weekly inspecting approximately one-quarter of the equipment at each visit.

In commenting on the factory assembly of the automatic switchboard, he stated that 10 per cent of the labor cost of installation was saved by factory assembly of a board which he had installed.

G. H. Thomas said that on the Santa Fe railroad automatic substations are used for supplying the power for automatic train control where continuity is very necessary. His system has been operating for 2½ years with scarcely any trouble. A slight inspection is made daily and every three months a very complete inspection is made.

C. M. Gilt said that the Brooklyn Edison Company keeps operators in its automatic stations in order to restore service as quickly as possible in cases of unusual trouble. The company, however, contemplates installing totally automatic stations for supplying certain of its d-c. loads.

C. A. Butcher called attention to the fact that the automatic a-c. network protector is a further development of this class of station which is proving very satisfactory and in fact, amounts to a small automatic substation. He agreed with other speakers that a complete inspection at one-month intervals was better than cursory daily inspection. He called attention to the fact that a committee of the American Electrical Railway Association has prepared some valuable information on the ventilation of substations in such a way as to exclude dust which makes necessary frequent inspection. He cautioned against improper grounding of d-c. equipment, especially synchronous converters, and stated that the frame of such a machine should not be tied directly to the negative bus.

Mr. Butcher read a written discussion by R. J. Wensley which called attention to a supervisory control system used by the Alabama Power Company in connection with a long 110-kv. line. This control system operates sectionalizing disconnecting switches spaced about 15 mi. apart. Two wires installed on the tops of the "H" frame of the line are used for the supervisory control, in addition to being used as static guards and return circuits for ground relays. The control is effected by impulses of 500-cycle and 650-cycle currents. Selection is obtained by dialing impulses of one frequency.

Audible answering signals, originated by a buzzer at the distant point, check both the station called and the device selected. Operation is obtained through application of the second frequency by the dispatcher control key.

Mr. Ellyson, in closing the discussion, said that in the station which he had described there were 70 circuit breakers which operated from two to five times per day and that in the year 1926, there was not one failure.

Rectifier Session

Three papers on the subject of mercury-arc rectifiers were presented in the session on Friday morning at which Professor G. C. Shaad presided. These papers were as follows: *Steel-Tank Mercury-Arc Rectifiers*, by E. B. Shand, *Mercury-Arc Rectifiers*, by O. K. Marti, and *Application of Mercury-Arc Power Rectifiers*, by C. A. Butcher.

In discussing these papers B. Blasser said that according to his calculations for a city load the losses of a rectifier were somewhat less than the losses in a synchronous converter. This is particularly true for 60-cycle operation, he said.

In discussing the interference which might be caused to telephone circuits by operation of rectifiers on electric railways with ground return, R. G. McCurdy said that with a six-phase transformer connection (60-cycle) the telephone interference factor had been measured and that an average value might be stated as 100. For the 12-phase rectifier under the same conditions

the value would be 70, and for a synchronous converter the value would be under 20. The application of reactors to the rectifier circuits reduced the values to about 20. These values applied to interference from voltage and the interference from current depended on the load. He mentioned also that interference might be caused as well from the a-c. circuits when the rectifier is operating under heavy load.

C. Antonio described his experiences with a rectifier railway station which ran for eleven months with a leaking electrode, the vacuum being maintained by means of a pump. This rectifier often withstood momentary peaks of 300 per cent normal quite satisfactorily. In his opinion the rectifier has a number of advantages over the rotating converters, among which are: (1) It is noiseless; (2) it will handle very heavy loads suddenly applied; (3) it produces no interference with communication; (4) it has no flash-over nor commutation trouble, and (5) repairs are very small in comparison with those necessary for converters.

Alfred Herz said that the rectifier will allow increasing of voltage in present sub-stations, which will eliminate the necessity of increasing the number of substations on heavy electric traction lines, and that this is a great advantage as they are already spaced as close as 3½ mi. apart. He suggested that the electrodes might be oil-cooled so as to eliminate some of the troubles from electric leakage and electrolysis in the cooling water.

E. B. Shand, in commenting on Mr. Marti's paper, stated that the heat-dissipating ability of rectifiers is comparatively great when water is used for cooling and that probably it is greater than the heat-storing ability of rotating converters, depending, of course, on the cooling arrangement. In connection with interference to communication circuits, he pointed out that with inductive loads the harmonics in the rectifier circuit are reduced. However, on a circuit between a rectifier and a converter station, circulating harmonic currents will exist without much damping and these may cause interference. He suggested that either the telephone circuit or the rectifier circuit might be compensated to prevent such interference.

O. K. Marti said that on some of the rectifier installations which are still in the experimental stage, the maintenance cost has probably been rather large, but that when the stations have been put into regular operation, the maintenance cost will be greatly reduced. He said that he had never found it necessary to purify the mercury used in rectifiers. In commenting on the costs mentioned in Mr. Butcher's paper, he said that the cost for the building and foundation of a certain 5500-kw. rectifier station had been only $1800 and not $5000 as indicated. He said that the costs of rectifier stations for 600-volt operation were about equal to those of converter stations, but that as the voltage increases the rectifier has an increasing advantage in cost. In regard to interference with telephone circuits, he mentioned that in 900 European stations interference trouble was reported from only five. He claimed that radio cannot suffer any interference from operation of these stations.

Industrial Applications Session

The session on Friday afternoon was devoted to industrial applications of electricity in oil fields, flour mills, and in fabricating pipe lines. R. L. Baldwin presided at this meeting.

The first paper of the session, which was read by S. M. DeCamp was *Electricity as Applied to the Petroleum Industry*, by B. K. Howard. Mr. Howard gave information on the consumption of electrical power by the petroleum companies, telling of some of the uses of electricity in this industry as well as some of the records established by electrical power.

The next paper, *Electricity for Oil Well Drilling* was presented by the author, L. J. Murphy. In discussing this paper, J. H. McCormick said he knew of a certain 2000-ft. well in Pennsylvania which had been drilled with gear units and jack shaft at an average consumption of 3 kw-hr. per foot. He stated that this low power consumption was probably due to the nature of the soil. Mr. Murphy stated that he knew of a case in which a 2000-ft. well was drilled for 2.4 kw-hr. per foot. He said, however, that with the equipment used for this work high hoisting speeds are not possible and that possibly the same limitations applied to the equipment mentioned by Mr. McCormick. W. G. Taylor called attention to the fact that there is another type of differential drive which is called the Halliburton. This type of drive employs only one motor and Mr. Taylor stated that it had been relatively free from troubles in operation.

Next on the program was the paper, *Electric Welding of Pipes*, by J. F. Lincoln, which was presented by Mr. W. H. Kincaid. In discussing this paper, H. R. Park agreed that the electrically welded pipe has a number of advantages for oil and gas transmission lines. The construction of such lines, he said, is usually a hurry-up job and the welded pipe can be made more quickly than cast pipe. In the matter of preventing leakage also, the welded pipe excels. In regard to the use of lighter and larger pipe, Mr. Park said he did not think this would become the practise because the pipes have to be bent in the field and it is more difficult to bend large pipes. He stated he estimated a reduction of cost of about 45 per cent for the welded pipe, though a number of mill men had predicted a reduction of about 30 per cent. W. L. Warner stated that the tests described in the paper are severe enough, but they are not as severe as the tests of the American Welding Society.

The last paper in this session, entitled *Electricity in the Milling Industries* was read by its author, G. C. Meyer. Mr. Meyer outlined briefly the principal divisions of the flour mill and told how electricity has been applied to drive these divisions. He also gave extensive information on power consumption and on horse power required for the various drives in flour mills. M. D. Bell stated that Mr. Meyer's figures apply to small or medium-sized plants but not to the largest flour mills. He explained that the use of high-voltage distribution has disadvantages because the continuous operation of the mill makes cleaning the insulators difficult. He mentioned that interruptions in a flour mill operated electrically do not have very serious consequences because the entire mill stops completely. This is better than having parts of the mill drive along at half speed after other parts have stopped. He mentioned several other uses of electricity in flour mills, speaking particularly of the use of thermocouples for indicating wheat temperature within the bins. A. S. Rufsvold said that one of the disadvantages of employing a clutch with a synchronous motor drive has been overcome in a type of synchronous motor which has a built-in clutch mounted upon the same shaft as the rotor of the motor. This mounting secures good alignment and saves floor space. The clutch is automatic in operation. M. M. Boggess stated that the advantages of the synchronous motor could be retained while the disadvantages of the clutch are eliminated by employing the supersynchronous motor which may be made to start the load as gradually as desired.

Branch Conference

On Wednesday afternoon, March 16, a conference of the Branches of the Southwest District was held. The conference was opened by Vice-President A. E. Bettis, who turned the meeting over to Professor G. C. Shaad, as temporary chairman. An election for permanent chairman of the District Committee on Student Activities was held, and Professor Shaad was unanimously chosen for this position. All of the Branches in the District were represented at this council by professors and students.

A general outline of the activities of each Branch was given, usually by the Student representative of the Branch. In most cases it was said about two meetings per month are held. The Students conduct practically all of the affairs of every Branch in the District. The difficulty of getting good attendance was mentioned by quite a number, and some of the Branches stated

that they held social features in connection with their meetings to increase their attendance. One Branch stated that almost all of its meetings had been in the nature of inspection trips, and it was suggested by several that some kind of a meal during the meeting results in increased attendance. One Branch said that it intended to discuss Institute papers at some of its meetings, although this had not yet been tried out.

As the Branches of this District will send a delegate to the coming Summer Convention at Detroit, it was necessary to choose a representative, and Professor Shaad was chosen by vote to act in this capacity.

Regional Meeting at Bethlehem, Pa. April 21, 22 and 23

A very profitable and enjoyable meeting has been planned by the Committee in charge of the Regional Meeting of the Middle Eastern District of the Institute, which will be held in Bethlehem, Pa., April 21, 22 and 23. Technical papers on a wide variety of subjects of particular interest to electrical engineers in industrial plants and central stations, attractive inspection trips and other features will make this meeting one of the most successful. Details of the features and the schedule of events are given in the following paragraphs.

Technical Sessions

Four technical sessions will be held, two on Thursday and two on Friday. A total of ten papers will be presented, all on important subjects of current interest. The report of the committee on voltage standardization on Friday afternoon is of especial interest and importance. The session on Friday morning derives added interest from the fact that it deals with the application of electricity to iron and steel production, cement manufacture, and anthracite coal mining,—the three leading industries of the Lehigh Valley.

All of the technical sessions will be held at the Hotel Bethlehem except the Thursday afternoon session, which will be held in the Alumni Memorial Building on the Lehigh University Campus.

Dinner

On Thursday evening at 7:00 p. m. an informal dinner will be held in the ball room of the Hotel Bethlehem. It is planned to have as the principal speaker, M. H. Aylesworth, President of the National Broadcasting Company. Members are especially urged to bring their friends. Ladies are invited. Informal dancing will follow Mr. Aylesworth's address.

The price of the dinner is $3.50 per cover. Reservations should be made in advance.

Friday Evening Lecture

On Friday evening Dr. Ernst J. Berg, Professor of Electrical Engineering, Union College, will speak on his personal reminiscences of Sir Oliver Heaviside and Dr. C. P. Steinmetz. This lecture will be held in the Alumni Memorial Building, Lehigh University.

Inspection Trips

It is planned to make the inspection trips which will take place on Saturday an important feature of the meeting. The Lehigh Valley Section of the Institute, which is host to this meeting, includes in its territory in addition to Bethlehem the thriving industrial cities of Easton, Phillipsburg, Allentown, Reading, Pottsville, Hazleton, Wilkes-Barre and Scranton. This territory constitutes an industrial district which, for the variety and size of its plants and the quantity of their output, is rivaled by few similar districts in the world. The existence of this wide variety of industries within easy reach of Bethlehem has made it possible to arrange an exceptionally interesting program of inspection trips, which includes visits to the following places:

Ingersoll-Rand Co., Phillipsburg, N. J.

International Motor Company, Mack Plant, Allentown, Pa.

Bethlehem Steel Company, Bethlehem, Pa.

Roller-Smith Co., Bethlehem, Pa.

Lehigh Coal & Navigation Company, Lansford, Pa.

Penna. Power and Light Company, Siegfried Substation, Allentown, Pa.

Lehigh Portland Cement Co., Sandt's Eddy Plant.

Other Trips. The laboratories and other buildings of Lehigh University will be open during the meeting and visitors will be welcome. Arrangements can be made, for those interested, to visit silk mills; American Steel and Wire Co., Allentown; Warren Paper Mill, Milford, N. J., where a sectional paper-mill drive may be seen in operation; the generating plant of the Metropolitan Edison Company at Middletown, a modern pulverized-fuel plant; Lafayette College, Easton, Pa., and many other places of interest.

Meeting of Student Counselors

The Counselors and the Chairmen of the Student Branches of the District will meet on Saturday morning, April 23, in the Electrical Engineering Building of Lehigh University, at 9 a. m. The first Student Branch of the Institute was formed at Lehigh University twenty-five years ago. It is hoped that Prof. Charles F. Scott, who was largely instrumental in bringing into existence the Student Branches, will be present.

On Friday the Counselors will be the guests at luncheon of Mr. A. G. Pierce, Vice-President for the District.

Register by Mail

Those who expect to attend the meeting should notify the Registration Committee in advance. By doing so they will be assured of finding their badges in readiness at the registration desk upon their arrival.

Hotel Accommodations

A list of hotels with their rates is given below. Those desiring accommodations should reserve them directly with the hotel at which they desire to stay. The Hotel Bethlehem will be convention headquarters but also hotels in Easton and Allentown have been included in the list.

	Single room		Double room	
	Without Bath	With Bath	Without Bath	With Bath
Bethlehem				
Hotel Bethlehem*	$2.50 up	$3.00 up	$4.00 up	$5.00
Hotel Wyandotte	2.00	2.50	4.00	4.50
American Hotel	1.50–2.00	2.00–3.00	3.00–3.50	4.50–5.00
Sun Inn	2.00		4.00	
Allentown				
Hotel Traylor	2.00–3.00	2.50–4.50	4.00–4.50	5.50–7.00
Hotel Allen	2.00–2.50	3.00–4.50	3.50–4.00	5.00–6.00
Easton				
Hotel Easton	2.50	3.00 up	4.00	4.50 up
Karldon Hotel	2.00–2.50	3.00–3.50	3.50 up	5.00 up
Hotel Huntington	2.00–2.50	3.00	3.00–4.00	5.00

*Headquarters hotel.

Committees

The general committee in charge of the meeting is as follows: W. E. Lloyd, Jr., Chairman; C. S. Ripley, Secretary; R. T. Greer, W. H. Lesser, A. G. Pierce, D. M. Simons and M. R. Woodward.

The local committee chairmen directly in charge of various activities are as follows: Finance, D. M. Petty; Program, J. L. Beaver; Transportation, L. C. Josephs; Trips, H. G. Harvey; Registration, James Huebner; Banquet, M. R. Woodward; Publicity, L. R. Woodhull; and Attendance, Geo. M. Keenan. G. W. Brooks is Secretary of the local committee.

PROGRAM

Thursday, 9:00 A. M.

HOTEL BETHLEHEM

Registration.

THURSDAY, 10:00 A. M.

HOTEL BETHLEHEM

Introductory Remarks, A. G. Pierce, Vice-President, A. I. E. E.

Oil Circuit Breaker Development, R. M. Spurck, General Electric Company.

This paper tells of (1) conditions which govern the design of a breaker of a given interrupting capacity, (2) the standardization that has been accomplished in rating breakers, and (3) trends in the design of breakers constructed to meet operating requirements.

Reducing Losses in Electrical Systems, J. B. Moorhouse, Central Illinois Public Service Company.

Methods of reducing losses in distribution systems particularly for towns of moderate size are given in this paper. Details are given on testing transformer loads and there is considerable discussion on the proper loading of transformers.

THURSDAY, 2:00 P. M.

ALUMNI MEMORIAL BLDG., LEHIGH UNIVERSITY

Improvements in Large Induction Motors, D. F. Alexander, Westinghouse Elec. & Mfg. Company.

A history of the evolution of induction motors is given in this paper. It includes extensive information on the main features of the modern induction motor particularly the larger sizes.

Intercommunication in Industrial Plants, L. A. Cutshall, Automatic Electric, Inc.

The uses and benefits of communication systems within industrial plants are related in this paper. Telephone, call-service, emergency-alarm and watchman's systems are discussed. Automatic telephones and their advantages are treated at length.

The Mercury Arc Rectifier, O. K. Marti and Harold Winograd, American Brown Boveri Electric Corp.

A general description of the operation of mercury arc rectifiers and their control equipment is furnished in this paper, and several installations described.

THURSDAY, 7:00 P. M.

HOTEL BETHLEHEM

Informal Dinner.

Address by M. H. Aylesworth, President, National Broadcasting Co., followed by informal dancing.

Ladies invited.

FRIDAY, 9:30 A. M.

HOTEL BETHLEHEM

Application of Electricity in Cement Mills, W. E. North, Coplay Cement Mfg. Company.

The advantages of electric drive for cement mills are enumerated in this paper and general pointers on installing electrical equipment are given. The electrical installation recently made in a modern cement plant is described.

Application of Electric Power to Anthracite Mining, E. B. Wagner, Lehigh Valley Coal Company.

Electricity is successfully meeting all power requirements in the anthracite mining field except for the drilling of hard rock. This paper points out the advantages of electric power and explains methods of application which realize these advantages to the fullest extent.

Recent Developments in Electric Drive for Rolling Mills, L. A. Umansky, General Electric Company.

This paper outlines how some of the problems of rolling-mill drive have been met. Among other schemes it describes particularly a new combination type of drive in which the "slip" energy of an induction motor (when running at low speed) is employed to drive other motors. The result is increased overall efficiency and reduced capacity of regulating apparatus required.

FRIDAY, 2:00 P. M.

HOTEL BETHLEHEM

Lightning and Its Effects on Transmission Lines, J. H. Cox, Westinghouse Electric & Mfg. Company.

A large number of records of surges produced on transmission lines by lightning are recorded in this paper. The records are analysed as to magnitude of voltage, steepness of wave front and possible effects on transmission systems.

Committee Report on Voltage Standardization, B. G. Jamieson, Commonwealth Edison Company.

This report will be an analysis of the discussion of voltage standardization presented at the 1927 Winter Convention of the A. I. E. E. The subject deals particularly with standardizing transmission voltages on which in turn depends electrical equipment of many kinds.

FRIDAY, 8:00 P. M.

ALUMNI MEMORIAL BLDG., LEHIGH UNIVERSITY

Personal Reminiscences of Heaviside and Steinmetz, by Dr. Ernst J. Berg, Union College.

Summer Convention June 20-24 in Detroit

A most attractive program is being planned for the Summer Convention of the Institute which will be held in Detroit, June 20-24. The program will include the Annual Reports of the Technical Committees, in addition to a number of papers on timely subjects, such as power generation, electrical transportation, communication, electric arcs, transmission, distribution, etc.

In connection with the Convention it is proposed to take a three-day trip on Lake Huron, in which Mackinac Island and Georgian Bay will be visited. The possibilities of this trip are being studied by a special committee and if it is found feasible, announcements will be made later.

As usual during the Summer Convention, the delegates of the Institute Sections will meet in a conference under the auspices of the Sections Committee to be held on the first day of the Convention.

The General Committee in charge of this Convention is as follows: Alex Dow, Chairman; G. B. McCabe, Vice-chairman; Harold Cole, J. H. Foote, B. G. Jamieson, C. Kittredge, G. E. Lewis, A. H. Lovell, A. C. Marshall, A. A. Meyer, E. B. Meyer and Harold B. Smith.

Lake Trip Planned to Follow Summer Convention

A steamer trip from Detroit to Mackinac Island and Georgian Bay is being planned for Institute members and their guests, to start on the day after the coming Summer Convention. This will be a three-day trip, the first boat leaving Detroit, Saturday, June 25, a second one returning to Detroit, Tuesday, June 28.

All members who are interested in this trip are requested to write to Institute headquarters, New York, in order to help the committee in making its plans.

The trip will be made on two of the larger steamers traveling the Great Lakes. From Detroit to Mackinac, a steamer of the Detroit and Cleveland Navigation Company will be used. From Mackinac through Georgian Bay and back to Detroit the trip will be made on a steamer of the Chicago, Duluth and Georgian Bay Transit Company. The following is the schedule of this trip:

Lv. Detroit	Sat.	1:30 p. m.	D. & C.
Ar. Mackinac	Sun.	8:15 a. m.	
Lv. Mackinac	Sun.	4:30 p. m.	C. D. & G. B.
Ar. Parry Sound	Mon.	10:00 a. m.	
Lv. Parry Sound	Mon.	11:30 a. m.	
Ar. Detroit	Tues.	9:30 a. m.	

The cost of this round trip will be $42.50 and $45.50, including meals and berth. Two passengers must share each stateroom. The lower rate includes transportation on Deck C of the C. D. and G. B. Steamer, while the higher rate includes transportation on Deck D-E.

Those who desire may continue on a steamer from Detroit to Cleveland or Buffalo; also it will be possible to go from Detroit through Mackinac to Chicago, omitting the return trip from Mackinac through Georgian Bay to Detroit.

Although the plans for this trip are not definitely settled, if a sufficient number show interest, it will be made practically as outlined above. More complete information will be sent to those who contemplate taking the trip upon request.

Northeastern Regional Meeting at Pittsfield May 25-28

The fourth Regional Meeting of the Northeastern District of the Institute which will be held in Pittsfield, Mass., May 25-28, promises to be a very successful meeting. A large number of timely technical papers will be presented and the committee in charge plans other very enjoyable features.

The papers contemplated will include a symposium on measurements at high frequencies and papers on variable-ratio transformers, mechanical forces of electrical circuits, cable tests, dielectrics, motor characteristics, power-factor correction, etc.

A conference of students of the District will be held in connection with the meeting and a number of students will present papers at a session devoted to that purpose.

The committee which is making arrangements for this meeting is as follows: H. M. Hobart, Vice-President in District No. 1; A. C. Stevens, Secretary of District No. 1; W. H. Colburn, E. D. Dickinson, E. F. Gehrkens, C. H. Kline and A. E. Soderholm.

Further information on the Pittsfield meeting will be published in the May issue of the JOURNAL.

A. I. E. E. Annual Business Meeting New York, May 20

The annual business meeting of the A. I. E. E. will be held on Friday, May 20, 1927, at 8:15 p. m. (Daylight saving time), in the Engineering Societies Building, 33 West 39th Street, New York City. At this meeting will be presented the report of the Committee of Tellers on the annual election of Institute officers, the annual report of the Board of Directors for the year ending April 30, 1927, and such other matters as may need attention.

Following the business meeting, there will be a program under the auspices of the New York Section. More complete information will be published in the May issue of the JOURNAL.

FUTURE SECTION MEETINGS

Akron

Joint meeting of the Akron and Cleveland Sections at the Ohio Insulator Works, Barberton, Ohio. Some new researches and manufacturer's developments, including carrier-current inspection. April 21.

Inspection tour of the Avon Station of the Cleveland Electric Illuminating Company. In the evening the Annual Meeting and a banquet will be held. May 14.

Cleveland

Annual Meeting. Speaker: C. C. Chesney, National President, A. I. E. E. May 19.

Columbus

Talks by local members. Buffet lunch and smoker. April 22.

Annual Meeting. Prominent speaker and election of officers. May 27.

St. Louis

Annual Meeting. Election of officers. April 20.

Reyrolle Armor-Clad Switch Gear, by H. V. Nye, Allis Chalmers Co. May 18.

Schenectady

Smoker. April 30.

Sharon

Steel-Mill Electrification. April 5.

Address by a prominent engineer. May 3.

Washington, D. C.

Business Meeting. Cosmos Club, at 12:15 noon on April 12.

Vancouver

Hydroelectric Developments of the East Kootenay Power Co., by M. L. Wade. April 5.

Talk by W. P. Dobson, Vice-president, District No. 10, A. I. E. E. May 3.

New Uses of High-Frequency Electric Currents to be Demonstrated before New York Electrical Society

The meeting of the New York Electrical Society to be held 8.15 p. m., Wednesday, April 20th, will be devoted to some important investigations dealing with new uses for high-frequency electric currents commonly used in radio.

Dr. Harvey C. Rentschler, Westinghouse Elec. & Mfg. Co., will describe and illustrate his experiments with high-frequency electric furnaces by which very high temperatures can be produced in almost perfect vacua and without direct outside electric contact. In this way Dr. Rentschler has produced metallic thorium, metallic uranium, and other metals not previously available in pure form. He will also illustrate his work by a number of spectacular experiments.

Dr. Phillips Thomas, also of the Westinghouse Company, will discuss and illustrate some other features of recent high-frequency investigations, especially the production of relatively intense beams of radio waves at frequencies corresponding to wavelengths of only a few meters and with intensities approaching the transmission of power by radio.

Both the experiments of Dr. Rentschler and Dr. Thomas are among the newest of physical investigations in this field and also among the most promising for future importance.

All those interested are invited to be present in the Engineering Auditorium, 29 West 39th St., New York, N. Y. as guests of the New York Electrical Society.

Meetings for Oil-Power Week Announced

The National Committee has already announced 75 meetings as arranged for Oil-Power Week, April 18-23, with many more in prospect. The varied list of meeting places and the subjects to be discussed evidence the wide scope of this activity. Participants in this week of conferences include the following technical bodies: The American Society of Mechanical Engineers; American Chemical Society, Local Sections; American Petroleum Institute; American Society of Naval Engineers; National Association of Stationary Engineers, and the National Association of Practical Refrigerating Engineers. Everyone interested is very welcome to attend any meetings taking place in local vicinities, and Mr. Edgar J. Kates, Chairman of the National Committee, 29 West 39th Street, New York, N. Y. will gladly supply further information regarding them upon request.

Spring Convention of A. S. M. E.

The regular Spring Convention of The American Society of Mechanical Engineers will be held at White Sulphur Springs, May 23-26. The technical sessions planned give promise of much of interest and importance and the convenience and charm of location will afford opportunity for many added pleasures to those in attendance.

An "Institute of Chemistry"

The formation of the Institute of Chemistry by the American Chemical Society will, beginning with this year, bring together every summer at a technical educational center, chemists from national laboratories of industry and education. The suggestion that such a convention be held annually "for the promotion of science in America" has been approved and The Chemical Foundation, Inc. and Pennsylvania State College have agreed to furnish funds to put the plan in operation for the first session to be held at Pennsylvania State College during July 1927. Northwestern University has requested the privilege of being the second university to cooperate in the 1928 session, to be held at Evanston. Locations for the third and subsequent sessions are to be determined at a later and more current date.

A New Course in Fuel Engineering

Announcement is made of a new course in fuel engineering at the Towne Scientific School, University of Pennsylvania, beginning September 30, 1927.

This course is intended primarily for those who have the advantage of a complete undergraduate education of college grade and some practical experience in allied fields of engineering. A baccalaureate degree from an institution of recognized standing, provided the course included physics and chemistry, will also admit one to this new course. In exceptional cases where no degree has been obtained, but educational qualifications essentially equivalent to those required for the degree of Bachelor of Science are proved, admission will be granted, says Dean John Frazer. There will also be considered a limited number of applicants who are not holders of college degrees, but who are qualified to pursue work in special divisions of the general course. These, however, will be subject to the approval of the director of the course and the payment of fees designated. The period of study will include one academic year's graduate work in residence at the University of Pennsylvania and the degree of Master of Science in Fuel Engineering will be awarded upon its successful completion. Students desiring to enroll for the course should apply for full information to Dean John Frazer, Towne Scientific School, University of Pennsylvania, Philadelphia, Pa. The course embraces the following Departments: A. Fuel Resources; B. Mining Methods, (Preparation for market, distribution, storage and re-handling); C. Composition and Combustion of Fuels; D. Manufacture of Special Fuels; E. Uses of Fuels and Specifications for Purchase; F. Furnaces; G. Fuel Sampling, Analysis and Calorimetry; H. Fuel Testing in Heating and Power Appliances; I. Domestic Heating, Cooking and Smoke Elimination; J. Regulations Affecting Use of Water Power and Fuel Resources; K. Research; L. Electives.

Summer Course at Carnegie Institute of Technology

Courses in electricity are included in the Summer Session plans of the Carnegie Institute of Technology. The College of Industries will give six weeks' courses from June 27 to August 5 in Elementary Electric Wiring, Advanced Electric Wiring, Elementary Principles of Electricity, Advanced Electricity and Elementary Principles of Radio Communication. The Radio course, it is reported, has been an outstanding success in the summer school work for the past four years.

Johns Hopkins New Plan for University Work

Dr. Frank J. Goodnow, President of The Johns Hopkins University, has authorized the following statement in reference to the future of the School of Engineering:

"Much interest has been displayed in the New Plan for University work at The Johns Hopkins University. This plan applies particularly to the Philosophical Faculty. For the present, the School of Engineering will continue as formerly to offer its regular four year undergraduate courses and graduate instruction. Only such changes in curricula will be made as are necessary to conform with the modified courses in the College of Arts and Sciences."

A. I. E. E. Year Book

The 1927 issue of the Institute's Year Book is now ready for distribution and may be obtained upon application at headquarters. This contains an alphabetical and geographical cataloging of the membership revised to January 1, 1927; also copy of the Constitution, By-Laws, list of officers and committees and much other valuable information relating to Institute activities.

Arc Welding Prizes Established by Lincoln Electric Company

The American Society of Mechanical Engineers has accepted the custody of $17,500, to be awarded in three prizes of $10,000, $5000 and $2500, respectively for first, second and third prize for the "three best papers disclosing new information that will tend to advance the art of arc welding." This fund has been established through the generosity of the Lincoln Electric Company, organized by Paul M. Lincoln, Past-president of the Institute. The company is now under the management of his brothers, James F. Lincoln and John Cromwell Lincoln, who have also been members of the Institute since 1908.

These three awards will be presented at the 1928 Spring Meeting of The American Society of Mechanical Engineers and all competitors will be duly notified of the action of the judges. Full details regarding rules governing the competition may be obtained by addressing Calvin W. Rice, Secretary, 29 West 39th Street, New York, N. Y.

Changes Explained in Patent Practises

After the close of the last session of Congress some of the changes effected by the recent legislation in patent procedure and practise were reviewed by Commissioner of Patents, Thomas E. Robertson.

An amendment to existing laws requires patent owners to mark their devices with numbers instead of patent dates, thus simplifying patent search by making it unnecessary to review all patents issued on a given date.

Another bill increases the Board of Examiners-in-Chief from five to six, thus expediting the work of the Patent Office. In cases where there are more than 20 claims, the fee is increased $1.00 for each claim for both filing and printing. Appeals to the Circuit Court of Appeals will be permitted before ordering an accounting in infringement cases, thus saving thousands of dollars of expense.

Response to official action on appeals must be taken within six months instead of a year and if his case is forfeited the applicant must renew it within one year instead of two years as was formerly provided.

There is to be a single appeal within the Patent Office instead of appeals to both the Board of Examiners-in-Chief and to the Commissioner. A new Board of Appeals is provided, consisting of the Commissioner, two Assistant Commissioners, and the Examiners-in-Chief, three of whom shall constitute a quorum.

Procedure regarding appeals in the court has been changed so that the applicant can make his selection between appealing direct to the Court of Appeals of the District of Columbia or filing his bill in equity, but he cannot do both, as heretofore.

The enactment of these measures shows that the recommendations of the Committee on Patent Office Procedure, on which American Engineering Council was represented, are slowly being put into effect.

Modification of Waterpower Act Sought in Congress

Several bills before the Commerce Committee of the Senate and the Interstate and Foreign Commerce Committee of the House during the last session of Congress proposed a modification of the existing definition of navigable waters as it is used in the Federal Power Act. Although no action was taken on these measures, they were the subject of vigorous opposition from Secretary of War, Dwight F. Davis, Acting Chairman of the Federal Power Commission.

The engineers of the country, through American Engineering Council have opposed any action which would lead to nullification of the authority of the Federal Power Commission, since it is felt that the present system has worked well and has given the desired results to those interested in power projects, at the same

time retaining regulation and control of such projects to the extent necessary to the protection of federal interests. At forthcoming hearings on these measures opposition to them will continue to be exerted.

Federal Trade Commission Reports on Electric Power Industry

The report recently made by the Federal Trade Commission upon the request of the Senate, deals primarily with the regulation, control and ownership of commercial electric power companies.

At the time the Commission was directed to make this study it was charged in the Senate that the General Electric Company had acquired and was exercising a very extensive control over the electric power industry, either directly or indirectly through stockholders or interlocking directors, or otherwise. Consequently a comprehensive inquiry into the entire electric power industry was necessary.

The report shows that the General Electric Company has divested itself of the control charged against it and has not acquired other control. Although the General Electric Company had previously, through the Electric Bond and Share Company, built up an extensive organization of electric power companies, the field was said to be so large that abundant opportunity existed for any other group with sufficient financial backing and expert knowledge.

The report says that "the firm of Stone and Webster in many important respects was the pioneer in this activity, rather than the Electric Bond and Share Company. At any rate there has developed in fact, as already indicated, a number of other important electric power groups which, in 1924, far exceeded in the aggregate the General Electric group. Among these may be mentioned the "Insull interests," the North American Company, the Stone and Webster group, the Standard Gas and Electric (Byllesby) group, the Cities Service (Doherty) group, the Commonwealth Power group, etc."

The report continues that "one of the problems of public interest concerning some of the large electric power groups is the extreme degree to which 'pyramiding' has been carried in superposing a series of holding companies over the underlying operating companies so that in one instance less than a million dollar investment in the majority of the voting stock of the apex holding company gave in 1925 full control of the entire organization of the group, having scores of underlying companies and several hundred million dollars of investment. Such pyramiding not only affects the financial stability of the electric power industry, but also has a potential relation to the more general question of an undue concentration of control in the electric power industry. As the extensive grouping of electric power companies often brings their business into the field of interstate commerce, it presents a problem that calls for legislative consideration by Congress."

Figures as to the companies and extent of their control are given in the report.

The Commission also has in course of preparation a comprehensive discussion of the organization and control of the electric machinery and equipment industry, particularly with respect to the General Electric Company, and of competitive conditions in both of these industries.

No Progress Made in Disposal of Muscle Shoals

The Muscle Shoals problem received intermittent attention both in the Senate and House for weeks before the last Congress adjourned. It is understood that the House Military Affairs Committee tried to develop a measure which would have provided for acceptance of a bid from private corporations. Recent hearings were held before the Committee in regard to bids submitted by the Air Nitrate Corporation, the American Cyanimid Company and the Muscle Shoals Fertilizer Company, but no favorable action was taken on any of these proposals.

At the request of the Chairman of the Senate Committee on Agriculture and Forestry an analysis has been made by the Treasury Department, Income Tax Unit, Engineering Division, along the same lines as were followed in the preparation of previous analyses of offers for Muscle Shoals. No recommendations in regard to these offers have been made, however.

It is stated by those who have been following this legislation on Capitol Hill that there is growing sentiment in Congress for the operation of the property by the Government rather than let the power dam and nitrate plants remain idle.

Proposed Standards for Automatic Stations Available in Report Form

A proposed new section of the A. I. E. E. STANDARDS, No. 26, Standards for Automatic Standards, is now available in report form and may be obtained from A. I. E. E. headquarters, without charge. This report has been brought to its present form by the subcommittee on Automatic Stations of the Committee on Protective Devices. It is now issued to obtain criticism and suggestions before final adoption as an A. I. E. E. STANDARD. Address inquiries to H. E. Farrer, Secretary Standards Committee, A. I. E. E., 33 West 39th St., New York, N. Y.

Correction in Revision of Induction Motor Standards

On page 297 of the A. I. E. E. JOURNAL for March there was given a table on "Limiting Temperature Rises for General Purpose Open-Type Induction Motors," this table to be Table II in the revision of Section No. 9 of the A. I. E. E. Standards for Induction Motors and Induction Machines in General. In the third item of the table the temperature rise for collector rings and commutators was erroneously given as 35 deg. cent. It should have been 55 deg. cent.

ENGINEERING FOUNDATION

AFTER-COLLEGE EDUCATION THROUGH FOUNDER SOCIETIES AND ENGINEERING FOUNDATION

At a dinner conference on Cooperation in Research Activities called by Engineering Foundation on March 11th, to which the Presidents and Secretaries of Founder Societies, Chairmen of the Research Committees of the Societies, and Members of Engineering Foundation Board were invited, a statement was presented by the Director of Engineering Foundation showing how the Societies and the Foundation can cooperate in after-college education. The following is an abstract of it.

When the four Founder Societies, at Mr. Swasey's suggestion, set up Engineering Foundation, they created an institution of higher learning and a means for aiding their own development. Its possibilities as a construction implement in the hands of four powerful individual Societies working together, while each maintains its own particular skills and inspirations, have been but dimly perceived and feebly used.

The participation of the Engineering Societies in the cooperative endeavor for practical improvements in engineering education has revealed opportunities and obligations for the Societies to undertake definite functions in professional education and culture from the preparatory schools to the sunsets of careers. No usurpation of the duties of schools or colleges is proposed, but rather the performance of functions hitherto neglected.

Engineering research has functions in the extension of the formal education conducted in the halls of learning, and these functions can be made dynamic through the cooperation of the research committees of the Societies and Engineering Foundation.

The feeling of revolt at subordinate work often found in the young engineer can be eliminated by better instruction on this point, and by the use of better methods of introducing the graduate to workaday life, such as more intelligent leaders of industry are using with good success.

The Societies can help by enrolling students in their organizations as they are now doing and by leading all who are so inclined into their activities immediately after commencement. They can exploit "for the good of mankind" the curiosities, the energies, and the enthusiasms of "creative youth" by putting young men to work according to their interests and abilities in the boundless field of research.

The interest of deans and professors of engineering should be enlisted to report to Engineering Foundation a limited number of graduates worthy of consideration for places as members or associate workers in the special research committees of the Societies. Engineering Foundation could distribute such information among the Societies. This procedure would save a few years in getting these preferred men into fruitful Society service. They should be associated in committees with men of more experience, and the research activities of the Societies should be decentralized still more so groups in many places may work upon their own problems or parts of a larger program.

Engineering Foundation can serve as rallying post and clearing house for the research and other technical committees of the Societies, and thus assist in the development of programs of research which should include engineering, industry, government, and science, as well as those economic, personnel, and sociological problems which must be faced by engineers in administrative offices.

The reasons given for the ineffectiveness of committees are:

1. Lack of funds for assistants, for equipment, for travel and other incidental expenses.
2. Lack of permanent and central headquarters for the handling of records.
3. Lack of adequately manned and equipped central office to follow up the committees constantly.
4. Lack of a permanent clearing house and information bureau accessible to all committees of all Societies.

Research committee work should be made effective, with three purposes:

1. Increase of knowledge.
2. Development of young men coming into the Societies.
3. Advancement of the profession in its ability to promote the public welfare.

By these means the Societies can make a constructive contribution to "adult education," can advance the standing of the Profession, and enhance their own strength and usefulness.

PERSONAL MENTION

W. D. A. Peaslee has resigned from the position of general manager of the Daven Radio Corporation to accept a position of assistant to the president of the Underwood Laboratories.

Mr. Fred Allison has resigned his position as chief electrical and mechanical engineer of the Ford Motor Company and will engage in consulting engineering work with H. R. Van Deventer, Incorporated, this city. Mr. Allison has been connected with the Ford industries for over twenty years.

Harold Sleeman, electrical engineer of The R. Thomas & Sons Company, East Liverpool, Ohio, manufacturers of high-tension insulators, was awarded an Insull Medal for saving the life of a fellow workman in the experimental laboratory of the Company at the Lisbon plant.

George E. Roberts, vice-president of the National City Bank, has been elected a member-at-large of the Engineering Foundation. Mr. Roberts succeeds Elmer A. Sperry, gyroscope inventor, and will serve three years.

Dr. A. D. Little of Boston is also one of three new members-at-large.

Doctor William C. Bauer, who has been acting Director of the College of Engineering, Northwestern University, Evanston, Illinois, for the past six years, has been chosen director of the school. Doctor Bauer has been a member of many college faculties, including the University of Cincinnati, Baker University, University of Denver and Northwestern University. In 1918 he designed and built the Northwestern Barracks and was in charge of the N. U. Radio School to which 480 soldiers were assigned. Plans are now being formulated to combine the School of Engineering and the Armour Institute of Technology, completion of which plans it is anticipated will be accomplished within the next three or four years.

Maurice L. Sindeband, recently transferred to grade of Fellow of the Institute and a liberal contributor to its literature, has been elected a vice-president of the American Brown Boveri Electric Company and assumed his duties on March 1. Since 1915 Mr. Sindeband has been in the engineering department of the American Gas & Electric Company and he was recently elected a vice-president of this company in charge of the electrical engineering department. Several patents attest his ability as an inventor, and he has been very active as a writer of articles for the technical press. He is a member of the New York Electrical Society and has been an active and competent committee worker in both the Institute and the National Electric Light Association.

After receiving his education at Columbia University, Mr. Sindeband started his engineering career in 1907 with the New York Central Railroad. His next occupation was station-design work with the Brooklyn Edison Company, and in 1915 he entered the engineering department of the American Gas & Electric Company. His rise here was rapid, and in 1918 he was made electrical engineer. In this position he carried on extensive development work in transmission, carrier-current communication, oil circuit breakers and outdoor substations. He has been a leader in transmission-line and substation standardization work and has been connected intimately with tests and research on lightning protection and oil breakers. The rapid growth of the American Gas & Electric system called for working out large scale interconnection plans and the building up of a consolidated operating organization. It was his success in this executive engineering work which led to Mr. Sindeband's election as vice-president.

Obituary

Clarence Erle Reid, who has been professor of electrical engineering and head of the department at Kansas State Agricultural College, Manhattan, Kansas, since 1914, died on February 28.

Mr. Reid was born at Northwood, Ohio, on August 4, 1877. After completing two years at the Rose Polytechnic Institute, Terre Haute, Indiana, he taught physics in the Star City, Indiana, High School from 1896 to 1900. He was awarded the degree of Bachelor of Science in Electrical Engineering by Purdue University in 1902.

His experience in the electrical industries began in 1901 when he spent three months in the testing department and three months in the winding department of the Bullock Electric Company in Cincinnati.

He was instructor in electrical engineering at Purdue University, 1902-03, research assistant at the Bureau of Standards, 1903-05, instructor in electrical engineering at George Washington University, 1904-05, assistant professor of electrical engineering at Case School of Applied Science, 1905-09, and professor

of electrical engineering and head of the department at Mississippi Agricultural and Mechanical College from 1909 to 1914.

Professor Reid, who joined the Institute in 1903, has been deeply interested in Student Enrollment privileges. When the plan of appointing a Counselor for each Branch from the faculty of the institution at which it is located was adopted, he was appointed Counselor of the Kansas State Agricultural College Branch.

Dudley Farrand, vice-president of the Public Service Corporation of New Jersey, past-president of the National Electric Light Association and Fellow of the Institute, died March 8 at Fairhaven, N. J. Mr. Farrand was born at Bloomfield, N. J., February 21, 1869 and was a graduate of the Newark Academy. In 1887 he affiliated himself with the electric light and power company of Newark, which was the first central station started by the United Electric Lighting Company. With rapid promotion, Mr. Farrand became assistant general manager and then general manager of this company. Four years later he filled a like position with the electric department of the Public Service Corporation of New Jersey, and upon the formation of the Public Service Electric Company in 1910, to take over all the electric properties of the Public Service Corporation, Mr. Farrand was appointed its general manager. Five years later he was elected vice-president in addition to his general managership and in 1917 he assumed other duties as assistant to the president. In 1908, following his service as president of the National Electric Light Association, Mr. Farrand was appointed by President Roosevelt as technical adviser to the National Conservation Commission representing the electrical interests. Mr. Farrand was also a member of the American Society of Mechanical Engineers and of the Engineers' Club, New York City.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify the Institute Headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

B. J. Crahan, 807 8th St., Portsmouth, Ohio.
Victor Godly Cottell, 335 W. 78th St., New York, N. Y.
U. Harry Densmore, 164 W. Washington St., Chicago, Ill.
G. Hyan, 32 London St., East, Windsor, Ont., Canada.
W. E. Jervey, Jr., Georgia Rwy. & Pr. Co., Atlanta, Ga.
Gerald L. Jones, Ponce Electric Co., Ponce, P. R.
Harold C. Pease, 1653 Cliffview Road, Cleveland, Ohio.
H. N. Stroh, 3710 Forbes St., Oakland, Pittsburgh, Pa.
Frank H. Wainman, 2015 81st St., Brooklyn, N. Y.

Past Section Meetings

SECTION MEETINGS

Akron

The Electrification of the Rubber Reclaiming Industry, by A. P. Regal, Philadelphia Rubber Co. A motion picture, entitled "The Design, Construction, and Testing of Large Power Transformers," was shown. February 18. Attendance 33.

Baltimore

Influence of Residual Air and Moisture in Impregnated Paper Insulation, by Dr. J. B. Whitehead and Mr. F. Hamburger, Jr. Joint meeting with N. E. L. A. December 16. Attendance 245.

New Landmarks in Electrical Communication, by P. B. Findley, Bell Telephone Laboratories. The speaker demonstrated a radio loud speaker. January 21. Attendance 95.

Lightning and High-Voltage Phenomena, by F. W. Peek, Jr., General Electric Co. Illustrated with motion pictures. Joint meeting with Engineers' Club of Baltimore. February 18. Attendance 85.

Boston

The New England Industrial Situation, by E. H. Schell, Mass. Inst. of Tech;

Influence of State Laws on Amount and Cost of Industrial Production, by Major C. P. Wood, Lockwood-Greene Co., Inc.;

Taxation of Industries, by G. A. Ricker, Walworth Co.;

The Economics of Electrification, by Sidney Withington, N. Y., N. H. and H. R. R.;

Transportation Economics, by Samuel O. Dunn, Editor, *Railway Age;*

America's Increasing Industrial Efficiency, by Dr. E. D. Durand, U. S. Bureau of Foreign and Domestic Commerce;

The Limitation of Output, by Col. Chas. R. Gow, Consulting Engr., and

What is Going Wrong in New England, by R. W. Warren, Federal Reserve Bank of Boston. All-day joint meeting of all engineering societies in Boston, under the auspices of the Affiliated Technical Societies of Boston. A banquet was held in the evening. February 17. Attendance 200.

Recent Developments in High-Voltage Cables, by I. W. Middleton and E. W. Davis, Simplex Wire and Cable Co. February 24. Attendance 123.

Chicago

Recent Power Construction at Niagara Falls, by R. B. Williamson and F. Nagler, The Allis Chalmers Mfg. Co. Joint meeting with Electrical Section, W. S. E. February 28. Attendance 300.

Cleveland

Demonstration of the Vitaphone. February 8. Attendance 1650.

Arc Welding—Its Present and Future, by J. F. Lincoln, The Lincoln Electric Co. February 24. Attendance 50.

Columbus

Some Motive Power Problems in Railway Transportation, by S. T. Dodd, General Electric Co. Illustrated with moving pictures. January 28. Attendance 28.

Telephone Switching, by S. D. Williams, Bell Telephone Laboratories. Illustrated with motion pictures and slides. February 25. Attendance 35.

Connecticut

Men Who Have Made Science, with Particular Reference to the Electrical Science, by Dr. M. I. Pupin, Columbia University. A talk on the activities of the A. I. E. E. was also given by H. M. Hobart, Vice-President, North Eastern District. January 21. Attendance 128.

Power System Stability—A Mechanical Analogy, by R. D. Evans, Westinghouse Elec. & Mfg. Co. March 1. Attendance 60.

Denver

Demonstration of the Vitaphone. February 21. Attendance 125.

Annual College Branch Night. See report in first part of Student Activities section. February 25.

Detroit-Ann Arbor

Short-Circuit Problems, by Prof. H. B. Dwight, Mass. Inst. of Tech. This was an afternoon and evening meeting, the evening meeting being preceded by a dinner. February 14. Attendance 150.

Erie

Automatic Train Control, by W. S. Reichard, General Railway Signal Co. Illustrated with slides. February 15. Attendance 150.

Fort Wayne

The Chamber of Commerce of Fort Wayne and Its Work in Civic Affairs, by H. E. Bodine, Secretary, Chamber of Commerce; Albert Book, Chairman, Wholesalers' and Jobbers' Bureau; Frank Bohn, Chairman, Civic Council; R. L. Fitzgerald, Chairman, Smoke Prevention; and M. S. Mahurin, Chairman, Better Yards Bureau. Several motion pictures were shown, one of which was entitled "The Iron Trail Around the World." February 17. Attendance 30.

Indianapolis-Lafayette

Oscillography, by J. W. Legg, Westinghouse Elec. & Mfg. Co. February 18. Attendance 145.

Ithaca

Modern Reproduction of Sound, by M. B. Long, Bell Telephone Laboratories. February 18. Attendance 155.

Kansas City

Long Distance Telephony, by H. H. Nance, American Tel. & Tel. Co. Illustrated with slides and diagrams. February 21. Attendance 38.

Lehigh Valley

Super-Synchronous Motors, by G. E. Cassidy, General Electric Co.;

Internal Clutch Motor, by M. A. Hyde, Westinghouse Elec. & Mfg. Co., and

Control of Synchronous Motors, by J. H. Hall, The Electric Controller and Mfg. Co. January 14. Attendance 140.

Lightning and Transmission Lines, by M. L. Sindeband, American Gas and Elec. Co., and

The Federal Constitution and the Engineer, by G. E. Stevenson, Stevens and Knight. A motion picture, showing construction and method of testing large transformers, was shown. A dinner preceded the meeting. An inspection trip was made in the afternoon to the suburban plant of the Scranton Electric Co. February 26. Attendance 147.

Los Angeles

Wire Transmission of Pictures, by H. W. Hitchcock, Southern California Telephone Co. Illustrated by lantern slides and demonstrated by essential elements of the equipment.

Radio Broadcasting and Radio Telephony, by A. P. Hill, Southern California Telephone Co. Illustrated and demonstrated. A talk was also given by P. M. Downing, Vice-president; District No. 8, A. I. E. E., who spoke on the aims, activities and accomplishments of the National Body. March 1. Attendance 308.

Lynn

Ladies Night. February 16. Attendance 500.

Refrigeration, by Mr. Timmerman, General Electric Co. March 2. Attendance 250.

Minnesota

The Electrification of the Great Northern Railroad in the Cascade Mountains, by Ernest Marshall, Great Northern Railway. February 24. Attendance 70.

Niagara Frontier

Electricity in the Industries, by R. H. Rogerts, General Electric Co. Illustrated with slides. February 4. Attendance 16.

Power System Stability, by C. F. Wagner, Westinghouse Elec. & Mfg. Co. Illustrated with slides and a mechanical model. Motion pictures, entitled respectively "Behind the Microscope" and "Construction of Power Transformers," were shown. March 4. Attendance 113.

Philadelphia

X-Rays in the Sciences, Arts, and Medicine, by W. C. Barker, M. D. Illustrated with slides. February 14. Attendance 130.

Pittsburgh

The Quoddy Tidal Power Project, by D. P. Cooper. February 8. Attendance 380.

Power System Stability—A Mechanical Analogue, by C. L. Fortescue, Westinghouse Elec. & Mfg. Co. March 8. Attendance 370.

Pittsfield

Relaying of Power Systems, by Robert Treat, General Electric Co. February 8. Attendance 70.

Petroleum, by R. L. Welch, American Petroleum Institute. February 15. Attendance 100.

Aviation, by Major Ira Longanecker, First Corps Area. The Lecture was followed by motion pictures, showing the bombing tests of the Army and Navy and the 1926 air maneuvers. A dinner preceded the meeting. March 1. Attendance 350.

Portland

Recent Advances in Electrical Communication, by L. S. O'Roark, Bell Telephone Laboratories. January 19. Attendance 60.

City Planning, by W. R. B. Wilcox, Eugene, Oregon. February 18. Attendance 60.

Providence

The Lands of Buddha, by Prof. H. B. Smith, Worcester Polytechnic Institute. Illustrated with slides. February 24. Attendance 70.

Rochester

National and International Standardization, by C. E. Skinner, Westinghouse Electric & Mfg. Co. February 4. Attendance 50.

St. Louis

Developments in the Manufacture of Copper Wire, by S. McMullen, Western Electric Co. Illustrated by slides and motion pictures. February 16. Attendance 62.

San Francisco

Recent Advances in Electrical Communication, by L. S. O'Roark, Bell Telephone Laboratories. Illustrated by motion pictures and demonstrated by suitable apparatus. A dinner preceded the meeting. February 4. Attendance 375.

Schenectady

Opportunities in the Application Engineering Departments of the General Electric Co. Symposium by R. C. Muir, H. H. Dewey and H. L. Andrews. February 4. Attendance 175.

Talking Motion Pictures, by C. W. Stone. Demonstrated. February 18. Attendance 500.

Seattle

Automatic Train Control, by R. C. Charlton, Oregon-Washington Railroad and Navigation Co. Illustrated with slides. February 15. Attendance 80.

Sharon

The Diesel-Electric Locomotive, by N. W. Storer, Westinghouse Elec. & Mfg. Co. March 1. Attendance 71.

Springfield

Behind the Pyramids, by G. A. Webster, National Carbon Co. February 21. Attendance 37.

Syracuse

Advantages in Steam Engineering, Eskill Berg, General Electric Co. February 28. Attendance 211.

Toledo

Visualization of Power Surges on Transmission Lines, by A. P. Fugill, Westinghouse Elec. & Mfg. Co. Illustrated with charts and a dynamic model. February 15. Attendance 48.

The Technical Man as a Citizen, by L. M. Gram, University of Michigan. Joint meeting of technical societies of Toledo, preceded by a dinner. February 25. Attendance 80.

Toronto

The Recent Development and Construction of Induction Motors, by M. Foster, Canadian General Electric Co. February 11. Attendance 74.

Urbana

Magnetic Fields, by R. E. Doherty, General Electric Co. February 17. Attendance 240.

Utah

Informal Discussion of Utah Legislature, by President Irvine, Utah State Senate, and Speaker Jorgensen, Utah State House. Joint meeting with Utah Society of Engineers. January 19. Attendance 156.

Reminiscences of Early Electrical Developments, by P. N. Nunn. Joint meeting with Electrical League of Utah and Utah Society of Engineers. February 15. Attendance 308.

A. I. E. E. Student Activities

NEW YORK SECTION STUDENT CONVENTION APRIL 8

The New York Section of the Institute will hold its second annual Student Convention on Friday, April 8, 1927. The meeting will cover an entire day and evening. The morning will be devoted to inspection trips by the students only. The afternoon session, in Room 1, Fifth Floor, Engineering Building, 33 West 39th Street, New York City will be occupied by the presentation of student papers in competition for the prize of $25.00 in gold offered by the New York Section. There are eight colleges in the territory of the Section giving courses in electrical engineering, and these will be entered in the competition. Following the afternoon session, a dinner will be held at the Fraternity Club, but because of limited accommodations, only those obtaining tickets in advance will be admitted. The charge will be $1.50 per cover. The morning and afternoon programs have been arranged entirely by committees of students and will be carried out solely under their direction.

The evening session will be a regular meeting of the New York Section especially designed to be of interest to students. Dr. Willis R. Whitney, Director, Research Laboratory, General Electric Company, has been obtained as the speaker. He is one of the gifted speakers in the electrical field and has spoken before the Section on several previous occasions. While the exact title of his talk for this occasion cannot be given at the present time, all members of the New York Section can be assured of a profitable and interesting evening.

The detailed program follows:

Morning Session

Inspection trips to Harrison Lamp Works; Kearney Power Station; Bell Telephone Laboratories; U. S. S. *Milwaukee*.

Afternoon Session

2:30 p. m., Room 1, Fifth Floor, Engineering Building, 33 West 39th Street, New York, N. Y.

1. Welcoming address by E. B. Meyer, Chairman, New York Section.
2. *The Engineer's Place in Civilization*, by E. C. Siddons, Rutgers.
3. *A Six-Year Engineering Course*, by John Balet, Columbia.
4. *Methods of Stage Lighting*, by P. H. Taylor, Stevens Institute.
5. Motion Picture: "Should Men Walk Home."
6. *Railway Signaling*, by H. T. Wilhelm, Cooper Union.
7. *Automatic Train Control*, by R. W. Jenkins, Newark College of Engineering cooperating with the D. L. & W. R. R.
8. *The Transmission of Motion Pictures by Radio*, by J. I. Heller, Brooklyn Polytechnic Institute.
9. *Crystal Oscillators*, by C. Ligh, New York University

Dinner

6:30 p. m. Fraternity Club, 38th Street and Madison Avenue, New York City. $1.50 per cover. Admission by ticket only.

Evening Session

8:15 p. m. Engineering Auditorium, Engineering Building.

Speaker: Dr. Willis R. Whitney, Director, Research Laboratory, General Electric Company.
(Subject to be announced later.)

NORTHWEST DISTRICT AWARDS BEST BRANCH PAPER PRIZE FOR 1926

At a meeting of the Executive Committee of District No. 9, six papers which had been presented at Student Branch meetings during 1926 and submitted in competition for the District prize were considered.

The prize was unanimously awarded to C. H. Bjorquist and H. E. Rhoads, both members of the Oregon Agricultural College Branch, for their paper entitled *The Influence of Line Voltage upon Induction Motor Characteristics*. This paper was presented at a Student Branch meeting held at Portland on April 9, 1926, attended by the Portland Sections of the A. I. E. E. and N. E. L. A., but conducted entirely by the O. A. C. Branch.

The prize consists of $25 from the national treasury of the Institute and a suitable certificate of award issued by the officers of the District.

Samuel Thompson received honorable mention for a paper entitled *Hydro Power Resources of the United States*, which was presented before the Montana State College Branch on November 18, 1926.

THE INFLUENCE OF LINE VOLTAGE UPON INDUCTION MOTOR CHARACTERISTICS†

BY
C. H. Bjorquist* and H. E. Rhoads*
Enrolled Students of the A. I. E. E.

An abridgment of a paper for which the authors were awarded the Best Branch Paper Prize in Geographical District No. 9 for 1926. A copy of the paper is on file at Institute headquarters.

Changes in the frequency and voltage of the power supply to an induction motor have important influences upon its operating characteristics.

Prime movers and their governors have been perfected to such a degree that the effects of frequency variations are confined largely to the use of motors on systems having frequencies slightly different from that for which they were designed.

Line voltage, on the other hand, is always subject to considerable variation due to fluctuations in load and other changes in a system. This investigation is confined, therefore, entirely to an analysis of the effects of changes in line voltage upon induction motor characteristics.

The tests were made upon a 40-h. p., 220-volt, three-phase, 1200 rev. per min., squirrel-cage induction motor, used to drive a centrifugal pump.

Constants were determined, and the complete characteristics of the motor were calculated by the "equivalent circuit method" for 180, 200, 220, and 240 volts.

The usually considered characteristics of an induction motor are efficiency, power factor, speed, torque, and current,—all expressed as functions of horse power output. Thermal characteristics are of great importance, and are dependent upon the losses in the machine and its mechanical design; *i. e.*, provisions for the dissipation of heat. In this investigation, however, the thermal characteristics were not studied.

Efficiency

The losses in an induction motor are:

A. Core—(Changing slightly with load due to variation in impedance voltage drop.)

B. Friction and windage—(Considered as constant over the range of operation.)

C. $I^2 R$—(Variable) (Resistance of windings at 75 deg. cent. used.)

At low values of load, the $I^2 R$ loss is low and the losses *A* and *B* predominate. Since they increase when the voltage rises, the efficiency decreases with increase in voltage.

*Both seniors in electrical engineering at Oregon Agricultural College, 1925-26.

†Presented in a Student Branch program before the Portland Sections of the A. I. E. E. and N. E. L. A. on April 9, 1926.

At high values of load, the $I^2 R$ loss predominates, and at a given load it is greater at lower voltages. Therefore, at a given load, the efficiency increases as the voltage rises.

The point of transition occurs at a load which causes the sum of the losses A and B to change by the same amount as the change in $I^2 R$ when the voltage varies.

POWER FACTOR

The power factor of an induction motor is dependent upon the load current, the impressed voltage, the magnetizing current, and the reactance.

At any given load, an increase in voltage causes a considerable increase in the exciting component and a decrease in the load component of the current. Since at low values of load the exciting-current increase is the predominating variation caused by increase in voltage, the power factor decreases as the voltage increases.

When the output is high and the voltage low, the rotor speed must be lower than it would be at normal voltage, to permit the cutting of a sufficient number of lines of force. The rotor reactance is proportional to the slip, causing the power factor to be lower. Hence at high values of output, the power factor increases as the voltage rises.

SPEED

Speed is a function of the output. An increase in voltage increases the excitation and permits the cutting of the necessary flux at a higher speed. Therefore, for a given load, the speed increases as the voltage rises.

TORQUE

Torque increases as frequency decreases, and is proportional to the square of the effective component of voltage.

Starting torque is proportional to the square of the voltage.

INPUT

Up to rated horse power output, the input at a given load increases only very slightly as the voltage is reduced from 240 to 180 volts. As the output increases above rated value, the input at a given load rises more and more rapidly with reduction in voltage.

COMPUTED RESULTS AND CURVES

The paper contains tables of computed results and curve sheets showing the complete characteristics of the motor at the voltages mentioned above and over a wide range of load.

ACKNOWLEDGMENT

The writers express their appreciation of the advice and assistance rendered them in the preparation of the paper by Professor F. O. McMillan of the Department of Electrical Engineering of the Oregon Agricultural College.

HYDRO POWER RESOURCES OF THE UNITED STATES†

BY

SAMUEL THOMPSON

An abridgment of a paper for which the author received honorable mention in the competition for the Best Branch Paper Prize in Geographical District No. 9 for 1926. A copy of the paper is on file at Institute headquarters.

SYNOPSIS

This paper describes the hydro power situation as it exists in the United States today, with semi-detailed descriptions of some of the more important power developments. The hydro power system of Montana is discussed at some length because that state is almost entirely dependent upon water power.

A brief description of the procedure in estimating potential water power is followed by tables of estimated potential and developed capacity.

The interconnection of hydro and steam plants for the purpose of stabilizing the power industry and extending the advantages of waterpower among more people is discussed.

CONCLUSIONS

The total potential waterpower resources of the United States as given by the U. S. Geological Survey, including all sites capable of developing over one hundred horse power, on the basis of power available half of the time, are 55,000,000 h. p. Of this, approximately 20 per cent has been developed. Much of the remaining 80 per cent consists of sites either of such small capacity or so remote from power markets that their development would not be profitable at present or in the near future. The undeveloped potential waterpower in the United States which can be developed at such an investment cost as to produce electrical energy more cheaply than it can be produced by steam does not exceed 10,000,000 h. p.

If all available sites which could be developed profitably were utilized, water power would be capable of supplying only 40 per cent of our present requirements, as compared with the 20 per cent now being supplied by it. Waterpower is today,and will continue to be, an important source of supply, but it will always produce much less than one-half the total amount of power required, and there is serious doubt that it will ever produce more than one-fourth.

The overall efficiency of a hydroelectric generating unit built in 1912 is about 60 per cent, while that of one built in 1925 is about 86 per cent.

The rapid advance in the art of transmission and distribution of electric power, the extension of transmission lines, and the combining of the smaller power companies or their absorption by the larger systems are making economically feasible the development of sites heretofore unavailable.

Each step in the nation's power-development plan must justify itself, and, if the developments are fundamentally sound and capably carried out, there should result a great era of water power and transmission development. Waterpower developments are assets of increasing value.

By the development of waterpower and transmission to places where electrical energy is required, a waste is used to supply a need. The use of this energy to lift the burdens of humanity makes a net gain for civilization, and tends to eliminate slavery. This gives assurance for the future, for "an increasing population requires progress, progress requires profits, profits require efficiency—and we may claim, in all confidence, that modern efficiency requires electric power."‡

DENVER SECTION HAS STUDENT PROGRAM

The regular monthly meeting of the Denver Section held on February 25, 1927 was planned in cooperation with the Student Branches of the Institute at the University of Colorado and the University of Denver, and the entire program was supplied by the Students.

After a banquet and a program of college music, the following papers were presented:

The Causes and Effects of Distorted Wave Forms in Power Systems and Neighboring Circuits. R. G. Lorraine, University of Colorado.

A Short History of Engineering. R. F. Frantz, University of Denver.

Generator Voltage Regulators. O. H. Polk, University of Colorado.

This paper was based on original research carried out in the University of Colorado laboratories.

Measurement of High Temperature by Thermoelectricity. Cecil Dingman, University of Denver.

The attendance was approximately 100, including about 35 Enrolled Students of the Institute.

†Presented by Mr. Thompson, as a student, before Montana State College Branch on November 18, 1926.

‡F. G. Baum, "Atlas of U. S. A. Electric Power Industry."

CONFERENCE ON STUDENT ACTIVITIES AT BOULDER COLORADO

A Conference on Student Activities was held at the University of Colorado on February 26, 1927, under the auspices of the Committee on Student Activities of the Sixth Geographical District.

Opening remarks were made by Dean H. S. Evans of the College of Engineering, University of Colorado, Vice-President H. S. Sands, Sixth District, and District Secretary R. B. Bonney.

With Vice-President Sands presiding, the following program was presented, and opportunity was given for discussion after each address:

How Can the Section Help the Student Branch? Professor G. H. Sechrist, Counselor, University of Wyoming Branch.

Suitable Materials for Branch Programs. Arthur Eielson, Chairman, University of North Dakota Branch.

The Real Function of the Student Branch. Professor B. B. Brackett, Counselor, University of South Dakota Branch.

The Duties of a Counselor. Professor F. W. Norris, Counselor, University of Nebraska Branch.

How Can Student Interest in the A. I. E. E. be Stimulated? Professor J. O. Kammerman, Counselor, South Dakota State School of Mines.

Remarks by Professor Dungan, University of Colorado.

How Often Should Meetings be Held? Professor R. E. Nyswander, Counselor, University of Denver Branch.

The Advisability of Joint Meetings with Other Student Organizations such as the A. S. M. E. and A. S. C. E. H. R. Newsome, Chairman, Colorado State Agricultural College Branch.

The above program was followed by several inspection trips and a banquet. The attendance at the Conference was about 55.

STUDENT CONVENTION AT DREXEL INSTITUTE

The third annual Student Convention of the eastern region of Geographical District No. 2 was held at Drexel Institute, Philadelphia, under the sponsorship of the Philadelphia Section, on March 21, 1927.

Dean R. C. Disque of Drexel Institute presided at the morning technical session, and the following program was presented.

Address of Welcome, Dr. K. G. Matheson, President of Drexel Institute.

Hysteresis in Laminated Permalloy Cores, Winthrop Allen, Princeton University.

A discussion of the chief characteristics of permalloy, based on laboratory tests by the author.

Carrier Current Telephony, J. G. Haydock, University of Pennsylvania.

The development and use of some of the principal parts of carrier current equipment.

Paper Mill Drives, J. B. Calkin, Haverford College.

The author described the processes used in the manufacture of paper, the types of drive available, and the best methods of speed control to meet the exacting requirements.

Radio Pictures, Theodore Rights, Lehigh University.

A description of the method used for transmitting pictures by wire was followed by a discussion of the present status of work being done on such transmission by radio.

The papers held the interest of all present, and there was some discussion after the presentation of each.

All delegates were guests of the Drexel Institute at luncheon.

At 1:30 five parties started on trips of inspection as follows:

1. Baldwin Locomotive Works (Eddystone Shops.)
2. General Electric Co. (Switchboard Factory).
3. Richmond Generating Station, Philadelphia Electric Co.
4. a. Leeds & Northrup Co.
   b. Atwater Kent Manufacturing Co.
5. a. Schuylkill Outdoor Substation, Philadelphia Electric Co.
   b. Converter Substation, Pennsylvania Railroad Co.

Following the above trips, there was an inspection of the Drexel Institute plant.

An evening dinner was held jointly with the Philadelphia Section, and music was furnished by a student orchestra.

A cup offered by Drexel Institute for the permanent possession of the Branch which presented the best paper was awarded to the University of Pennsylvania Branch for the paper "Carrier Current Telephony" by J. G. Haydock. The cup was presented to him with appropriate remarks by Dean Disque who presided.

The principal feature of the evening program was an address by Professor F. H. Green, Head Master of the Pennington School for Boys, on the subject, *The Spirit in Which to Work.* This was a very interesting and inspiring discussion of those principles of work which are essential for success in any profession, and was admirably enlivened by many anecdotes and jokes.

The meeting was concluded by stunts and music furnished by the Pennsylvania, Lehigh and Drexel Branches.

The Branches represented at the Convention were Deleware, Drexel, Haverford, Lafayette, Lehigh, Pennsylvania, Princeton, Swarthmore, and Villa Nova. The Student attendance was 166, and faculty men from several schools were present.

The Convention as a whole was a very interesting and enjoyable one. Much credit is due those who planned and carried out the various parts of the program.

PAST BRANCH MEETINGS

Municipal University of Akron

A motion picture, entitled "The Audion," was shown. Mr. D. Schregardus, Ohio Bell Telephone Co., supplemented the picture with a talk. February 11. Attendance 45.

Alabama Polytechnic Institute

The Importance of Physics and Mathematics to Engineering, by Prof. A. S. Dunstan. February 17. Attendance 36.

Motion pictures, entitled respectively "King of the Rails," "Electrical Giant," "The Potter's Wheel" and "The Busy Body," were shown. February 24. Attendance 54.

Advancement in Illumination During the Year of 1926, by C. T. Ingersoll, student;

Economic Value of Steam Railroad Electrification, by S. L. Hancock, student;

Summer Work of 1926, by P. E. Sandlin, student, and

Debate, W. B. Bernett and J. P. Lynch, students, Resolved: That All New Businesses in Alabama Should Be Tax-Free For a Period of Five Years. Won by negative. March 3. Attendance 50.

Smoker. March 11. Attendance 47.

University of Arizona

Electric Annealing, by Mr. Ellicock, and

Structural Features of Steam-Electric Turbine, by Mr. Glascock. January 8. Attendance 19.

Some Electrical Records Broken in 1926, by Mr. Sturges, and

Eliminating the Oxides and Nitrates in a Welded Joint, by Mr. Stroud. January 15. Attendance 19.

Motion pictures, entitled "X-Rays" and "Lightning," were shown. February 5. Attendance 19.

The Photoelectric Cell, by Mr. Sharpe;

Air Cooling of Generators, by Mr. Sturges;

Contact Resistance, by Mr. Riggins, and

Electric Furnace, by Mr. Mitchell. February 12. Attendance 19.

Some Experiments in High-Frequency Sounds, by Mr. McAllister;

Selenium, by Mr. Humbert, and

Mercury Watthour Meters, by Mr. Hopkins. February 19. Attendance 19.

Motion picture, entitled "Power," was shown. February 26. Attendance 19.

University of Arkansas

A motion picture, entitled "The Single Ridge," was shown. February 3. Attendance 20.

The Stowger Automatic Telephone, by Julian Edwards. February 15. Attendance 13.

Armour Institute of Technology

Photography and Engineering, by M. T. Goetz and C. E. Kenney, students. February 17. Attendance 25.

Brooklyn Polytechnic Institute

The Electrification of Railroads, by O. K. Marti, Brown Boveri Co. Illustrated by slides, diagrams and moving pictures. Joint meeting with A. S. M. E. and A. S. C. E. February 17. Attendance 300.

California Institute of Technology

The Cosmic Ray, by Dr. I. S. Bowen. The speaker demonstrated the apparatus that was used in making self-recording observations of ionization at high altitudes.

Neon Gas Filled Signs, by Mr. Thompson, Electrical Products Co. February 24. Attendance 23.

University of California

Business Meeting. January 12. Attendance 31.

Personnel and Management of the Bell Telephone Laboratories, Inc., by L. S. O'Roark. February 3. Attendance 70.

Business Meeting. February 9. Attendance 20.

Business Meeting. February 16. Attendance 16.

Carnegie Institute of Technology

Smoker. February 11. Attendance 95.

Evolution and Description of the Grimes Radio Receiving Circuit, by W. H. Seibert, student. A motion picture, entitled "Manufacture of Okonite Products," was shown. March 2. Attendance 22.

Case School of Applied Science

What Every Engineer Should Know about Arc Welding, by Mr. Dreese, The Lincoln Electric Co. Illustrated. February 9. Attendance 31.

Life and Work of Galvani, by J. F. Spenks;

Aids to References, by H. C. Bingham;

Life and Work of Volta, by M. S. Schonvizer, and

Life and Work of Coulomb, by C. R. Mosman. February 12. Attendance 54.

The Life of Hans Oersted, by W. C. Swanker, student;

Aids to References, by G. L. Bub, student;

The Life of Ampere, by M. C. Finehauf, student, and

The Life of Ohm, by A. W. Hahn, student. February 19. Attendance 52.

Motion pictures, entitled respectively "Manufacture of Incandescent Lamps," "Cotton—Seed to Cloth," and "Sugar Refining." February 26. Attendance 45.

Russia and My Experience There, by R. J. Kappanadze, student. Supper Meeting. March 2. Attendance 40.

Public Utilities, by F. A. Fountain, Ohio Public Service Co. March 5. Attendance 49.

Catholic University of America

Trans-Atlantic Cables and Communication, by Prof. MacKavanaugh. Meeting followed by smoker. February 15. Attendance 16.

Clemson College

Debate; Resolved: That the Study of Mechanical Engineering is of More Value to an Engineer Employed in Railroad Electrification than is the Study of Electrical Engineering. Participated in by S. L. Gillespie and J. A. Warren, A. S. M. E.; A. P. Wylie and W. J. Googe, A. I. E. E. Joint meeting with A. S. M. E. March 3. Attendance 32.

Colorado Agricultural College

Business Meeting. February 14. Attendance 9.

Television, by Raymond Dickinson. Reports on the A. I. E. E. Student Convention at the University of Colorado were made by Harold Newsome and Harry Ericson. February 28. Attendance 9.

University of Colorado

Westinghouse, the Institution, by P. W. Kirkpatrick;

The Apprenticeship Course Twenty Years Ago, by William Trudgian;

Reminiscences, by W. H. Bullock;

Service Department Problems, by A. F. MacCallum, and

Accomplishments, by H. S. Sands, Vice-President, District No. 6, A. I. E. E. All of the speakers were representatives of the Westinghouse Elec & Mfg. Co. February 9. Attendance 72.

Economics of Automatic Substations, by W. H. Casey, Denver Tramway Co. Motion pictures, entitled "The Automatic Railway Substation," and "Supervisory Control of Substations," were shown. February 23. Attendance 37.

Annual College Branch Night of Denver Section. See report in first part of Student Activities section. February 25.

Cooper Union

The Development of the Telephone Circuit, by H. F. May, New York Telephone Co. February 18. Attendance 50.

Motion pictures, entitled "Laying the Atlantic Cable off Newfoundland," and "Zonite," were shown. The following officers were elected: Chairman, E. T. Reynolds; Vice-Chairman, Frank Congilose; Secretary, Wilfred Henschel. March 11. Attendance 40.

University of Denver

Business Meeting. February 24. Attendance 15.

Annual College Branch Night of Denver Section. See report in first part of Student Activities Section. February 25.

Economies Effected by Automatic Substations, by Mr. Casey, Denver Tramway Co. Motion pictures, entitled respectively "Making of Mazda Lamps," "Supervisory Control," and "Automatic Substations," were shown. March 4. Attendance 25.

University of Florida

Steam Turbine Development, by Mr. Lyman, General Electric Co. Illustrated. February 21. Attendance 32.

University of Idaho

Radio Interference, by Carl Clair, student; and

Construction of Transformers, by Cecil Balkow, student. Illustrated. A report on the A. I. E. E. meeting at Portland, Oregon, was given by Professor J. H. Johnson, and a short talk about the Engineering School at Oregon Agricultural College by Mr. Gartin. March 1. Attendance 29.

Iowa State College

Opportunities With the Bell System, by E. J. Bonneson. February 8. Attendance 21.

Kansas State College

Engineering Achievements, in 1926, by W. M. Hixon, student;

The Use of Carrier Current in Telephony, by Ralph Herman, student, and

Alternating-Current Commutator Motors, and *A 110-Ton Gas-Electric Storage Battery Locomotive*, by Prof. C. E. Reid. Illustrated. February 7. Attendance 85.

University of Kansas

Talks were given on the installation and design of the radio-sending station which is being placed in the Bowersock Mill, by O. W. Towner and W. W. Weedfall, students. February 17. Attendance 31.

Ancient Egyptian Architecture, by Prof. Goldsmith. Illustrated. March 10. Attendance 46.

Lafayette College

Diesel Electric Tug Boats, by Prof. G. G. Mercer. Illustrated with slides. March 5. Attendance 21.

Lehigh University

The Transmission of Radio Pictures, by H. T. Rights, student. A motion picture, entitled "Portable Electricity," was shown. March 11. Attendance 53.

Lewis Institute

Business Meeting. February 21. Attendance 14.

Business Meeting. March 8. Attendance 18.

Louisiana State University

A motion picture, entitled "Story of the Electric Meter," was shown. February 11. Attendance 17.

Marquette University

Electric Arc Welding, by K. L. Hansen, Northwestern Mfg. Co. February 3. Attendance 36.

Massachusetts Institute of Technology

Inspection trip to Generating Station of the Edison Electric Illuminating Company. February 16. Attendance 40.

Engineering School of Milwaukee

Central Station Protective Devices, by Mr. Pfandhoeffer, General Electric Co. A motion picture, entitled "King of the Rails," was also shown. February 23. Attendance 50.

The Application of Thermo-Relays in Across-the-Line Starters, by Ellis Lithgow, Allen Bradley Co. March 2. Attendance 15.

University of Minnesota

The Electrification of the Great Northern Railway in the Cascade Mountains, by Ernest Marshall, Great Northern Railway. Illustrated. Joint meeting with Minnesota Section. Fe ruary 24. Attendance 70.

University of Missouri

Step-by-Step Machine Switching, by O. S. McDaniel, student, and

Details of Machine-Switching Selector and Connector, by J. K. Nebel, student. March 7. Attendance 41.

Mississippi Agricultural and Mechanical College

Business Meeting. March 3. Attendance 24.

Montana State College

Developments of Steam Railroad Electrification in 1926, by E. L. Brentnall, and

Application of Carbon Brushes to Electrical Machines, by H. Wilkie. February 17. Attendance 165.

University of Nebraska

Telephotography, by R. A. Cushman. Short talks were also given by G. E. Bickely, Bell Telephone Co., and E. I. Pollard, student. A motion picture, entitled "New York's Newest Subway." It was decided to have a student talk for every meeting. March 2. Attendance 45.

University of Nevada

Telephone Repeaters, by Mr. Fremuth, Pacific Tel. & Tel. Co. September 26. Attendance 30.

Essentials of Success for Engineers not Taught in School, by A. H. Babcock, Consulting Engineer, Southern Pacific Co. October 20. Attendance 26.

The Invention of the Telephone, by Mr. McNally, Bell Telephone Co. A motion picture, entitled "The Evolution of the Telephone," was shown. November 21. Attendance 59.

Business Meeting. December 8. Attendance 15.

Automatic Machines, by Mr. Garrett, Westinghouse Elec. & Mfg. Co. January 19. Attendance 32.

Inventors That I Have Known, by L. S. O'Roark, Bell Telephone Laboratories, Inc. The meeting was opened by a moving picture, entitled "The Magic of Communication." February 2. Attendance 90.

Relays, by Mr. Melarkey, General Electric Co. February 16. Attendance 45.

Newark College of Engineering

The Slide Rule, by Dean A. R. Cullimore. February 16. Attendance 52.

What I Expect in the Young Engineer I am Going to Employ, by A. E. Petrie, Bell Telephone Laboratories, Inc. March 2. Attendance 27.

University of New Hampshire

Superpower, by F. B. Moody, student, and

Grounding of Electric Circuits, by H. M. Lawry, student. February 16. Attendance 41.

Manufacture of Lead Storage Batteries, by S. W. Roberts, student, and

Farm Lighting Systems, by J. M. Lee, student. February 23. Attendance 39.

A motion picture, entitled "The Magic of Communication," was shown. March 2. Attendance 88.

Northeastern University

The Modern Fire Alarm Signaling, by C. F. Beach, Gamewell Fire Alarm Telegraph Co. February 15. Attendance 45.

University of Notre Dame

Survey of Achievements of General Electric Co., by Howard Dahl;

Development of Electrical Industries, by Rocco Peroni, and

History of Telephone Development, by Mr. Fenimore of Indiana Bell Telephone Co. February 21. Attendance 35.

Ohio University

Motion pictures, entitled respectively "The Story of an Electric Meter," and "Electrified Travelogues," were shown. February 15. Attendance 26.

Motion pictures, entitled "Rolling Steel by Electricity," "Volta's Discovery," and "From Coal to Electricity," were shown. March 2. Attendance 43.

Ohio Northern University

The Electrician's Work in Substation Construction, by Mr. Masters. February 17. Attendance 24.

Ohio State University

Engineering and Economics, by C. S. Coler, Westinghouse Electric & Mfg. Co. February 10. Attendance 110.

The Telephone Art, by Samuel Williams, Bell Telephone Laboratories, Inc. Illustrated with moving pictures of the development of the telephone and slides. February 25. Attendance 65.

Oklahoma Agricultural and Mechanical College

Motion pictures, entitled "Laying of a Deep Sea Cable," and "Waterpower," were shown. February 9. Attendance 26.

Motion pictures, entitled "My Hero," "That Big Little Fellow," and "The Pillars of Salt," were shown. March 9. Attendance 35.

University of Oklahoma

On account of poor attendance the meeting was adjourned and those present were the guests of Scabbard and Blade at a motion picture show held in the Engineering Building. February 17. Attendance 6.

Pennsylvania State College

Choosing Your Job, by Prof. C. L. Kinsloe. February 23. Attendance 70.

Motion picture, entitled "Behind the Pyramids," was displayed. March 9. Attendance 61.

University of Pittsburgh

Sleep Tested Electrically, by D. P. Mitchell, student, and

The Mother of Invention, by H. I. Metz, student. February 11. Attendance 27.

Economics in Engineering, by Dean Dexter S. Kimball, Cornell University. February 18. Attendance 150.

Sparks, by L. B. Biebel, student, and

Development and Use of "B" Batteries, by M. G. Jarrett. Mr. J. G. Patillo, one of last year's graduates, gave a short talk on life after graduation. February 25. Attendance 29.

Princeton University

Motor Bus Transportation, by A. F. Lukens, student. A short talk on Railway Electric Transportation in Its Early Stages Compared to the Motor Bus Transportation was given by Professor M. MacLaren. February 28. Attendance 7.

Purdue University

Magnetic Fields, by R. E. Doherty, General Electric Co. Illustrated with slides and films. February 15. Attendance 90.

Oscillography, by J. W. Legg, Westinghouse Electric & Mfg. Co. Illustrated with slides. Thirty-five members of the Indianapolis Lafayette Section attended the meeting. February 18. Attendance 150.

Transformers, Cut-Outs, and Lightning Arresters, by P. H. Hazelton and H. W. Pfandhoeser, General Electric Co. Electric Line Foremen, who were holding their third annual convention at Purdue, were invited to attend the meeting, and about one hundred were present. March 3. Attendance 120.

Rensselaer Polytechnic Institute

Not Engineering, by Dr. R. A. Patterson. The paper dealt with recent developments in astronomical science. February 15. Attendance 140.

Rutgers University

Energy, by J. Cost, student;

Porcelain Insulators, by J. E. Conover, student, and

The Progress of the Electric Power and Light Industry, by A. Rue, student. February 14. Attendance 22.

University of South Dakota

Business Meeting. The following officers were elected: Chairman, Stanley Boegler; Secretary, Lysle Crowell. February 21. Attendance 10.

Stanford University

Smoker. Short talks were given by Messrs. R. D. Boynton, Vice-Chairman, Stanford Branch; T. J. Hoover, Dean, Stanford Engineering School; H. L. Terwilliger, Vice-Chairman, San Francisco Section, A. S. M. E.; Shirley Baker, A. S. C. E., and D. I. Cone, Chairman, San Francisco Section, A. I. E. E. Joint meeting with A. S. M. E. and A. S. C. E. February 17. Attendance 65.

Business Meeting. February 28. Attendance 22.

Stevens Institute of Technology

The Gas-Fired Refrigerator, by N. C. Heyman. Joint meeting with A. S. M. E. and Stevens Engineering Society. January 12. Attendance 50.

The Application of Electric Transmission to Internal Combustion Engines for Transportation Purposes, by S. T. Dodd, General Electric Co. Joint meeting with A. S. M. E. and Stevens Engineering Society. February 23. Attendance 30.

Swarthmore College

The Cement Industry from the Earliest Times up to the Present, by R. A. Wahl, Portland Cement Association. Illustrated with motion pictures. The following officers were elected: President, Ayres Seaman; Vice-President, Watson Rulon; Secretary, Everett Irish; Treasurer, James Colket. Joint meeting with A. S. M. E. and A. S. C. E. February 14. Attendance 23.

Texas Agricultural and Mechanical College

Motion pictures, entitled "Super Power" and "Inventions of Edison's," were shown. February 17. Attendance 120.

University of Texas

Motion picture, entitled "Power Transformers," was shown. January 12. Attendance 34.

Business Meeting. The following officers were elected: Winter term: President, F. W. Langner; Vice-president, L. E. Brown; Secretary-Treasurer, V. S. Skinner; Corresponding Secretary, H. W. Zuch. Spring term: President, A. L. Mayfield; Vice-president, H. H. Chapmann; Secretary-Treasurer, L. L. Antes; Corresponding Secretary, H. W. Zuch. January 26. Attendance 12.

Virginia Polytechnic Institute

Submarine Cable, by a member of the Western Union Telegraph Co. March 2. Attendance 32.

State College of Washington

Engineering. This paper, written by Prof. C. E. Lucke, was read by Dean H. V. Carpenter. Dean Carpenter resigned his position as Counselor and Prof. R. D. Sloan was unanimously nominated to succeed him. The meeting was preceded by a banquet. February 16. Attendance 30.

Business Meeting. The following officers were elected: President, Earl Munson; Vice-President, Harvey Richardson; Secretary, C. E. Peterson; Treasurer, E. E. Martin. February 23. Attendance 41.

Washington and Lee University

A motion picture, supplied by the General Electric Co. and entitled "Electrification of the Panama Canal," was shown. The Branch acted as hosts to the general student body. March 10. Attendance 15.

Washington University

Telephone Scientists and Inventors That I Know, by L. S. O'Roark, Bell Telephone Laboratories, Inc. The speaker's talk was illustrated with slides showing the different departments of the laboratores and some of the men about whom he spoke. A motion picture, entitled "The Magic of Communication," was also shown. March 2. Attendance 50.

University of Washington

Some of the Problems Met by the E. E. Graduate, and What Graduate Electrical Engineers Are Doing Who Are Not Following Electrical Engineering, by Mr. Whitman. February 2. Attendance 25.

Research and Transmission Line Design, by C. M. Briggs. March 2. Attendance 12.

West Virginia University

Discussion of Contact Resistance, by H. S. Muller;
$8,000,000 for Light, by G. B. Pyles;
Non-Corrosion of Aluminum, by L. T. Knight;
Thawing Frozen Pipes by Electricity, by C. B. Binns;
Short Cuts in Calculations, by A. M. Kalo;
Advantages of Railway Electrification, by W. A. Williams;
Prevention of Electrolysis by Railway Currents, by P. E. Davis;
The Future in Farm Electrification, by G. R. Latham;
Back Stage, by D. Carle
Does Good Street Lighting Pay, by S. J. Donley, and
Railway Mail Service Cars, by C. M. Borror. February 18. Attendance 38.
Philadelphia Sesqui-Centennial, by W. F. Davis;
Johansson Gauges, by E. W. Conway;
Construction of Desk Stand Telephone, by S. C. Hill;
Transmission Towers, by E. G. Braid;
The Electric Range as a Load Builder, by F. M. Farry;
60,000 K. W. Turbo-Generator, by W. E. Vellines;
Electric Dehydration of Petroleum, by W. W. Reed;
K. L. I. Valve-Vacuum Tube, by P. J. Johnston;
Radio Interference from Lines Not in Service, by C. L. Parks, and
Trans-Atlantic Phone, by H. S. McGowan. February 25. Attendance 38.
Steam of the Ocean as a Science of Inexhaustable Energy, by M. S. Diaz;
Methods of Oil Production, by W. H. Nuhfer;
Discovery of 200-A Detector Tube, by W. T. Meyers;
Clock-Controlled Street Lighting, by I. L. Smith;
Relationship Between Physics and Electricity, by K. D. Stewart;
Stellite—A New Alloy, by R. O. Pletcher;
Trouble Hunting, by H. H. Hunter;
Radio Braodcasting in the Future, by J. Cricchi;
Resuscitation from Electric Shock, by L. S. Davis;
Boulder Dam, by A. L. Lindley;
The Simplest Element of All, by J. P. Paine; and
Radio Interference from Lines Not in Service, by E. R. Long. March 4. Attendance 38.

University of Wisconsin

Electrical and Mechanical Analogies, by Prof. C. M. Jansky. February 23. Attendance 20.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is adminstered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES FEB. 1-28, 1927

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

AMERIKAS DAMPFTURBINENBAU.

By E. A. Kraft. Berlin, V. D. I. Verlag, 1927. 116 pp., illus., 11 x 8 in., cloth. 14.-r. m.

An interesting report upon a tour of inspection and study of the American steam turbine industry, in which the author compares the designs of the principal American turbines with those of Europe and describes rather fully American methods of manufacture.

Efficiency is the main object of the European builder, says Dr. Kraft; reliability that of the American. Each land can learn from the other.

Chemistry of Rubber Manufacture; based on the 5th edition of "Chemistry of India Rubber" by Carl Otto Weber.

By Lothar E. Weber. Lond., Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1926. 372 pp., illus., diagrs., tables, 9 x 6 in., cloth. $9.00.

Instead of attempting to revise his father's book, Dr. Weber has preferred to replace it by an entirely new work which follows the broad outline of its predecessor but has been entirely re-written. It is intended to give a statement of our present knowledge of the chemistry of rubber, from the composition of the latter to that of the commercial product. The discussion covers vulcanization, synthetic rubber, compounding ingredients, reinforcing agents, softeners, accelerators, reclaiming and the chemical and physical examination of vulcanized rubber.

Commercial Air Transport.

By Lt.-Col. Ivo Edwards and F. Tymms. N. Y., Isaac Pitman & Sons, 1926. 163 pp., illus., map, 9 x 6 in., cloth. $2.50.

This little book, setting forth the basic principles of the operation of air transport lines and the ways in which development and progress are likely to occur, is intended primarily as a text-book for those preparing for membership in the British Institute of Transport. The author discusses subsidies, the relative advantages of state and private operation, the economics of the problem, ground organization, traffic control, routes, passengers, freights, mails, and a variety of other matters connected with the question.

Comprehensive Treatise on Inorganic and Theoretical Chemistry, v. 7.

By J. W. Mellor. N. Y., Longmans, Green & Co., 1927. 977 pp., 10 x 6 in., cloth. $20.00.

The elements considered in this volume include the important commercial ones, tin, lead, titanium and thorium; and also zirconium, hafnium, germanium and the inert gases. A comprehensive summary is given of the known data concerning the history, occurrence, extraction, preparation, physical properties and chemical properties of each element. As a further step toward the completion of the best encyclopedia of inorganic chemistry, in the English language, the volume will be welcome to all engaged in chemical investigations.

Controllers for Electric Motors.

By Henry Duvall James. 2d edition. N. Y., D. Van Nostrand Co., 1926. 522 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

Furnishes in one volume an account of the design and operation of control apparatus which aims to give students, engineers and users a good general idea of the subject. The first half of the book treats of the methods of control in use at present and of the more important types of apparatus. The latter half discusses some of the more important applications, including applications to mine hoists, pumps, machine tools, paper-mill and steel-mill machinery, cranes, ore bridges, elevators, oil wells and locomotives.

Cotton; history, species, varieties......culture......marketing and uses.

By Harry Bates Brown. N. Y., McGraw-Hill Book Co., 1927. 517 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

Intended as a compact survey of the cotton industry in its various aspects. The author, who is Professor of Cotton Breeding at Louisiana State University, covers cotton growing from the selection of the seed to the marketing of the cotton and the seed.

Diesel Engines, Marine and Stationary.

By Arthur H. Goldingham. 3rd edition. Lond., E. & F. N. Spon, 1927. 255 pp., illus., diagrs., plates, 9 x 6 in., cloth. 21 s.

The great progress in the design and construction of Diesel engines which has taken place since the second edition of this work appeared, has led to rewriting of the greater part of the book and to thorough revision throughout. The work is wide in scope, giving attention both to design and to operation. It includes many drawings and illustrations of late types of engines and gives data on the leading varieties of the Diesel engines of various makers.

Electric Development as an Aid to Agriculture.

By Guy E. Tripp. N. Y., G. P. Putnam's Sons, 1926. 78 pp., illus., map, 8 x 5 in., cloth. $1.25.

Aside from the use of electric power on the farm itself, the present extension of electric distributing systems to rural communities will be a great economic blessing to the farmer, in General Tripp's opinion, through other channels. Four of the essays in this little book discuss the decentralization of manufacturing that is anticipated and the social and economic effects that it will have by providing part-time employment for farmers and by bringing the market for farm products closer to the farm. The final essay discusses possible future electrical developments.

Gasoline Automobile......v. 1, The Gasoline Engine. 7th edition.

By P. M. Heldt. Nyack, N. Y., P. M. Heldt, 1926. 728 pp., illus., diagrs., 9 x 6 in., cloth. $8.00.

The treatise of which this forms the first part is one of the very few in the English language that considers the automobile from the point of view of the designer and manufacturer, rather than of the owner and repairer. Since 1911, seven editions have appeared as well as French and German translations.

The new edition has been entirely reset and largely rewritten. There is also a considerable increase in size and most of the illustrations and plates are new. The chapters dealing with the principal parts of the engine, with engine characteristics and with engine tests, have been rewritten and a chapter on heavy-oil engines has been added.

The book discusses the principles underlying the design of automobile engines and the practises followed. Special attention is paid to the relation between design and methods of manufacture.

Interpolation.

By J. F. Steffensen. Balt., Williams & Wilkins Co., 1927. 248 pp., 9 x 6 in., cloth. $8.00.

This work owes its existence to the lectures given by the author in recent years to actuarial students at the University of Copenhagen, and is, except for minor emendations, a translation of the Danish edition published in 1925. It is intended as a text-book and not as a treatise or handbook. The point of view adopted is that only those approximate formulas are to be included for which it is possible to derive a remainder-term simple enough to permit the calculation of limits to the error involved in the formula, and the aim has been to meet the needs of the practical computer rather than those of the mathematician.

Introduction to Contemporary Physics.

By Karl K. Darrow. N. Y., D. Van Nostrand Co., 1926. 453 pp., diagrs., 9 x 6 in., cloth. $6.00.

This volume includes, in a more systematic development, the substance of a series of articles which appeared in the Bell System Technical Journal under the title, "Some Contemporary Advances in Physics," together with much additional matter. Dr. Darrow's object is a unified account of the phenomena that the nuclear atom-model of Rutherford and Bohr is intended to interpret, such as the directly perceived properties of electrons and ions, the detachment of electrons from atoms, the deflections of flying charged particles by atoms, the transfer of energy from electrons and radiation to atoms, and the regularities of line spectra and band spectra.

Kleine Geologische Karte Von Europa.

By F. Beyschlag & W. Schriel. Herausgegeben von der Preussischen Geologischen Landesanstalt, 1925. Berlin, Verlag von Gebrüder Borntraeger. Map. Scale 1:10,000,000. 15.-mk.

This small map is clearly printed and shows a surprising amount of detail for its size. It is accompanied by a cover sheet showing the principal features of the structural geology of the continent.

The Lightning Graphs. Series 1, General.

By I. S. Dalgleish. Lond., Crosby Lockwood & Son, 1926. 12 pp., + 10 graphs, 7 x 10 in., cloth. 5 s. (Gift of Author).

The first instalment of a collection of nomographic charts intended to assist in frequently recurring calculations that can not be solved readily with a slide rule. The charts given in this volume enable the unknown variables in the three equations: $a^2 = b^2 + c^2$, $a^n = d$ and $\sqrt[m]{a} = d$, to be found directly to within one-half of one per cent. These equations cover the relationship between the sides of a right-angled triangle, give values of hyperbolic logarithms and reciprocals of all numbers.

Movable Bridges, v. 2; Machinery.

By Otis Ellis Hovey. N. Y., John Wiley & Sons, 1927. 344 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

The second volume of this treatise, which is devoted to the machinery of movable bridges, opens with a discussion of the power required to operate them. A method is given for deter-

mining the minimum power required, which has been tested by extended use in practise.

The general arrangements of the machinery, the appropriate materials, frictional resistance, motor torques and unit stresses are then discussed, after which the design of the machine elements most frequently used is treated in detail. Formulas, tables and charts planned to facilitate design are included. This section, says the author, can be used as a manual for the design of heavy, slow-moving machinery in general.

Appendixes include a model specification for movable bridges, an analysis of large sheaves loaded by ropes under tension, and a collection of miscellaneous data of use to the designer.

OUR MOBILE EARTH.

By Reginald Aldworth Daly. N. Y., Charles Scribner's Sons, 1926. 342 pp., illus., tables, 9 x 6 in., cloth. $5.00.

Discusses the mobility of the earth as expressed in earthquakes, volcanic action, broad warpings of the crust and in mountain building. The book contains the substance of a course of public lectures at the Lowell Institute of Boston and is intended for the general reader who wishes a review of current theories concerning the leading processes by which the earth has attained its present shape and structure, and of the reasons upon which these theories are based.

OXWELDER'S MANUAL. 9th edition. Long Island City, Oxweld Acetylene Co., 1926. 216 pp., illus., tables, 9 x 6 in., limp cloth. $1.00.

A practical handbook on methods and apparatus for welding and cutting with the oxy-acetylene flame. Directions are given for handling steel sheet, plate and pipe, cast-iron, brass, bronze, aluminum, copper and alloy steels, as well as for stelliting steel and iron.

PRACTICAL RADIO CONSTRUCTION AND REPAIRING.

By James A. Moyer and John F. Wostrel. N. Y., McGraw-Hill Book Co., 1927. 319 pp., diagrs., tables, 8 x 5 in., cloth. $2.00.

Intended as a guide for amateur constructors of receiving sets and for those who wish to know how to make minor repairs and improvements. Directions are given for building, testing and repairing of the important types of sets and such commonly used equipment as wave traps, trickle chargers, battery eliminators, loud speakers, etc. Super-heterodyne, short-wave, impedance-coupled and resistance-coupled sets are given special attention.

REPORT AND RECOMMENDATIONS OF THE METROPOLITAN STREET TRAFFIC SURVEY.

Prepared under the Street Traffic Committee of the Chicago Association of Commerce, by Miller McClintock. Chicago, Chic. Assoc. of Commerce, 1926. 292 pp., illus., maps, graphs, tables, 11 x 9 in., cloth. $5.00.

An unusually extensive and detailed study of street traffic conditions in Chicago, which will be of interest to engineers generally. The report gives valuable data on the use of streets, the effect of physical conditions upon traffic, the economic effects of congestion, accidents, methods of controlling traffic, pedestrian traffic, parking, policing, signs and signals. A proposed traffic ordinance is given, together with recommendations for the improvement of conditions.

SWITCHING EQUIPMENT FOR POWER CONTROL.

By Stephen Q. Hayes. 2nd edition. N. Y., McGraw-Hill Book Co., 1927. 556 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

This book is intended primarily for switchboard operators, but will also interest students of electrical engineering and serve engineers as a convenient aid in selecting equipment for special cases. The work describes the varieties of switching apparatus in use, discusses the main connections desired in a power house and the means for making them effectively and economically and considers the location and arrangement of switching apparatus in the power house.

The new edition replaces considerable parts of the first by new material. Attention is paid in it to European practise; more space is given to truck-type switch gear and automatic control, and also to machine voltage regulators.

TIEFBOHRWESEN, FÖRDERVERFAHREN UND ELEKTROTECHNIK IN DER ERDÖLINDUSTRIE.

By L. Steiner. Berlin, Julius Springer, 1926. 340 pp., illus., diagrs., 9 x 6 in., cloth. 27.-r. m.

A treatise upon the applications of electricity in the production and transportation of petroleum. The author describes in detail the use of electric drive for drilling, hoisting and pumping, and discusses more briefly the less special applications and the electrical machinery involved. The book is a convenient guide to present practise.

TREATISE ON THERMODYNAMICS.

By Max Planck. Trans. by Alexander Ogg. 3rd edition from the 7th German edition. Lond. & N. Y., Longmans, Green & Co., 1927. 297 pp., 9 x 6 in., cloth. $5.00.

This edition has been carefully revised, corrected and extended to bring it into agreement with the latest German edition. It is intended as an introductory text-book for students who have an elementary knowledge of physics, chemistry and the calculus.

UBER NIEDERSCHLAG UND ABFLUSS IM HOCHGEBIRGE.

By Otto Lütschg. Zürich, Schweizerischer Wasserwirtschaftsverband, 1926. (Verbandsschrift, no. 14. Veröffentlichung der Hydrologischen Abteilung der Schweizerischen Meteorologischen Zentralanstalt im Zürich). 479 pp., illus., diagrs., maps. tables, 12 x 9 in., paper. $8.00.

An exhaustive study, by a leading Swiss hydrologist, of precipitation and run-off in the region of Mattmark, in the Pennine Alps. It is an important contribution to the hydrology and glaciology of Switzerland, handsomely printed and illustrated. In addition to its direct bearing upon the question of the power resources of Switzerland, the book will interest other engineers for its scientific conclusions of general applicability.

UMLENKUNG EINES FREIEN FLUSSIGKEIT-STRAHLES AN EINER SENKRECHT ZUR STROMUNGSRICHTUNG STEHENDEN EBENEN PLATTE.

By Friedrich Reich. Berlin, V. D. I. Verlag, 1926. (Forschungsarbeiten auf dem gebiete des Ingenieurwesens, heft 290). 74 pp., illus., diagrs., tables, 11 x 8 in. paper. 8.-r. m.

A study of the proper form for the draft tubes of hydraulic turbines. The author has investigated the distribution of velocity and pressure in concentric draft tubes with flat plates and has determined the lines of flow. From these experiments an equation is developed. In addition the effect of varying the position of the plate is investigated and a method given for calculating the most effective position is presented.

UTILIZZAZIONE DELLE ACQUE PER IRRIGAZIONE.

By Corrado Ruggiero. Padova, Casa Editrice Dott. A. Milani, 1926. 494 pp., illus., diagrs., 10 x 7 in., paper. Price not quoted.

A comprehensive textbook on irrigation. The book surveys the subject systematically, giving attention both to theoretical considerations and to practise. The various irrigation projects in Italy are described in some detail.

X-RAYS AND ELECTRONS.

By Arthur H. Compton. N. Y., D. Van Nostrand Co., 1926. 403 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

The present work, the outgrowth of lectures given by the author to university students during the last five years, covers the whole field of X-ray physics. Certain parts of the field, in which Dr. Compton has been actively engaged in research are, however, discussed in greater detail than others. The book deals especially with the interpretation of the properties of X-rays in terms of the interaction between radiation and electrons, and is concerned with the problem of the structure of the atom and the nature of the X-rays themselves.

ZERSPANUNG. Sonderheft der Zeitschrift Maschinenbau, edited by V. D. I. Berlin, V. D. I. Verlag, 1926. 60 pp., diagrs., 12 x 9 in., paper. 6, 50 r. m.

Thirteen brief papers upon various questions relating to the cutting of metals, in which are presented the results of recent investigations of the proper form for tools, for lathes, planers, etc., the effects of speed, temperature and pressure, and similar matters.

ABWARMEVERWERTUNG ZUR HEIZUNG UND KRAFTERZEUGUNG.

By Hans Balcke. Berlin, V. D. I. Verlag, 1926. 208 pp., illus., diagrs., tables, 6 x 4 in., cloth. 4,80 mk.

A brief discussion of the utilization of waste heat for heating and for power production. The author discusses the sources of waste heat, the proper lines for its utilization and the elements of the plants for this purpose. The treatment, though condensed, is thoroughly practical and the book is intended as a pocketbook for the engineer.

Aerial Cableways.

By G. Ceretti. Lond., E. & F. N. Spon; N. Y., Spon & Chamberlain, 1927. 111 pp., illus., diagrs., tables, 7 x 4 in., boards. 5 s.

A brief collection of formulas, tables and practical observations, prepared by the principal of an important firm of Italian cableway builders.

Automobile Wiring Diagrams.

By Terrell Croft. N. Y., McGraw-Hill Book Co., 1927. 282 pp., illus., diagrs., 8 x 6 in., cloth. $3.00.

A collection of 262 diagrams showing the wiring of most of the passenger automobiles, trucks and motorcycles on the American market. A convenient reference book for repairmen.

Benjamin Garver Lamme, Electrical Engineer, an Autobiography.

N. Y., G. P. Putnam's Sons, 1926. 271 pp., illus., ports., 9 x 6 in., cloth. $3.00.

Of interest not only to the many friends of the author, but also for the information that it contributes to the history of electrical development in America. From 1889 until his death in 1924, Mr. Lamme was an outstanding figure among designers of electrical machinery, a powerful factor in the success of the Westinghouse Electric and Manufacturing Company.

While the book tells briefly of his boyhood and college days, it is chiefly a narrative of the first thirty years of his engineering practise. Various friends have supplemented the story by adding their recollections of the man.

Berechnung Der Wasserspiegellage.

By Paul Böss. Berlin, V. D. I. Verlag, 1927. (Forschungsarbeiten auf dem gebiete des ingenieurwesens, heft 284). 96 pp., illus., diagrs., plates, 11 x 8 in., paper. 7, 50 r. m.

An investigation of the effect of variations in flow upon the surface of streams. The author bases his study upon Bernouilli's theorem and the energy curve, and considers cases both of regular flow and of intermittent flow. Among the questions considered are the effects of changes in the slope or roughness of the channels, of enlargements or contractions caused by piers, changes in the elevation of the bed or by weirs, by hydraulic jump and by the artificial increase of influx or efflux. A method of calculation is presented, with the results of experiments at the hydraulic laboratory of the Karlsruhe Technical High School.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

DESIGNER to assist in development of electrical fixtures. Apply by letter. Location, Connecticut. X-20.

WANTED· Electrical Engineer with experience on fractional horse power motor design. Location Canton, Ohio, for an international advertised industry. In reply give experience, education, age, salary expected and full particulars. X-2020-C.

MEN AVAILABLE

A RECENT GRADUATE in Science and Electrical Engineering, seeks afternoon employment (part time—1 P. M. on) at either instructing in physics, mathematics or engineering, or in electrical engineering, radio engineering, or patent law. At present studying for a J. D. degree (in law) in the mornings. Good draftsman. College experience with thermionic vacuum tubes. Location, New York City only. C-1969.

SALES ENGINEER, college graduate, electrical and mechanical engineer, with six years' experience in construction of power plants and substations, desires connection with equipment manufacturer. Has sound business judgment, good economic training and is familiar with modern methods of sales promotion. C-692.

RADIOTRICIAN, 23, technical training, experienced in design, manufacture and testing of all types of radio equipment. Capable of assuming charge of laboratory or engineering department. Correspondence, with firms of reliability where position would give assurance of permanence and advancement, is invited. Available about May first. Location immaterial. C-2608.

TECHNICAL GRADUATE IN E. E., 25, single, six months' experience distribution office during spare time in college, fourteen months' Westinghouse training and engineering, desires engineering work in South America in power, distribution, control, or railway. Two or three years contract. Available after August 31st. C-2592.

ELECTRICAL ENGINEER, 32, single, college graduate, G. E. test and central station engineering department experience. At present employed station design department large public utility. Desires change to better. Prefers East or Southeast. Available one month's notice. C-2591.

ELECTRICAL ENGINEER, 33, married, technical graduate with eight years' experience in hydro-electric design, construction and operation and in power transmission and distribution. Wants position as design, construction or operating engineer for power company. Available at once. Location preferred, Western States. C-2614-72-C-7.

OPERATING ENGINEER, university graduate in electrical engineering, with four years of experience operating modern type power stations and substations with both automatic and remote control systems, desires job in engineering department of a public utility. Any location. 30 years old and single. C-2380.

ELECTRICAL ENGINEER, technical graduate, age 29, single. Five years' engineering experience with industrial electric control apparatus. Some sales experience. Desires position with manufacturer of electrical apparatus. Available immediately. B-6274.

ELECTRICAL ENGINEER, 37, married, twelve years' broad experience testing, experimental and design with large and well known companies, three years teaching. Desires permanent position with responsible company on experimental work leading to research or design. Available on short notice. Location preferred in United States. C-2515.

GRADUATE E. E., with extensive mechanical experience, desires Eastern location, preferably with firm of consulting electrical or industrial engineers, but exceptional opportunity in other work, including radio and automotive electric work considered. Would prefer location in which thirteen years of varied experience, including G. E. test, would be of value. C-2299.

PRODUCTION ENGINEER OR MANAGER, competent engineer and executive trained on production control, scheduling, machine operations, equipment, budgeting,

valuations, costs, wage incentives, with technical and college degrees and background of electrical and mechanical engineering experience with eleven years constructive record of development, desires position in Eastern States. Now engaged on installing production control methods in large organization. Age 32, married. B-9676.

ELECTRICAL ENGINEER, B. Sc. in E. E., 27, single, five years' experience in power plant construction, operation and maintenance, with ability to organize and supervise. At present employed in responsible position with one of the country's largest steam-electric power plants. Available at one month's notice as assistant to department-head or superintendent or similar position. Salary requirements $3000 per year. Location, New York, or vicinity. C-2666.

ELECTRICAL ENGINEER, age 27, married, B. S. in E. E., and E. E., five years' experience test supervision with public utility, one year's experience teaching. Editor, executive, statistician, organizer. Desires position with industrial organization. C-1346.

ELECTRICAL DESIGN DRAFTSMAN, 27, single, ten years experience in design work on hydro-electric power stations, substations (automatic railway and A. C. distribution), and overhead and underground distribution systems. Desires position with public utility. Available May 1st. Location, immaterial. B-8628.

GRADUATE OF BLISS IN PRACTICAL AND THEORETICAL ELECTRICAL ENGINEERING. Various experience in meter department and meter engineering; inspection of machine switching telephone exchange installation; and sales. Age 25 and single. Available at once. Location East. C-1570.

INDUSTRIAL ENGINEER, Mechanical and Electrical; past eight years electrical engineer of works employing 7000 men—400 men in electrical department, erecting, maintaining and operating 1500 motors—ordering spare and repair mechanical parts for 150 traveling cranes, 5 locomotive cranes, as well as specialized equipment. Technical graduate able to determine power and lighting requirements of all industrial shops, foundries and mills, as well as power plant. C-2651.

TEACHER IN ELECTRICAL ENGINEERING, 31, single, four years' teaching experience in an Eastern University of high standing. Holds M. E. E. and Ph. D. degrees from that university. Desires position as professor in a Technical school or University having opportunities for research. Available June 1927. B-4977.

COST REDUCTION AND MANUFACTURING EXECUTIVE, 38, electrical graduate with broad electrical and mechanical experience. Especially experienced in development, production development, and cost reduction as applied to manufacturing. Interested in work requiring vision and analytical, inventive, and executive abilities. C-1776.

GRADUATE ELECTRICAL ENGINEER, 1925, desires position with a manufacturing or construction company. Eighteen months' experience low and high tension cable inspection. Location, New York. Available two weeks. C-512.

PLANT ENGINEER, 38, technical graduate in electrical engineering, ten years' experience in layout, installation and maintenance of general shop equipment, at present employed as plant engineer of large industrial plant. C-2660.

ELECTRICAL ENGINEER, 22, R. P. I. graduate 1926, desires connection with a reliable firm in some branch of hydro-electric development work. Several years' experience in civil engineering work and construction work, power plant designing, and testing work in large public utility. Available in two weeks. Location preferred, United States. C-2667.

SALES ENGINEER, electrical graduate, 27, married, two years' test course and factory work, three years' varied engineering experience with public utility, desires position as sales engineer on salary plus commission basis to demonstrate ability for a sales executive position. Location, Eastern States. C-1524.

ELECTRICAL ENGINEER, 25, single, German college graduate, one and one-half years' experience in testing and calculation, nine months with large New York concern in construction of power houses. Speaks English, German and French. Location immaterial. Available in one week. C-2577.

E. E. ENGINEER, having had E. E. construction and also steam engineering, as well as Navy training, is trying to make a permanent connection where work and faithfulness will be appreciated. Can offer the best of references as to character and lines employed in. Had also three years' valuation and estimating work. Would like to return to South America, China, or Cuba. Married. Also has a working knowledge of Spanish. C-68.

ELECTRICAL ENGINEER, 29, married, graduate Ohio State University in electrical engineering, one and one-half years' work in commerce college, majored in economics and accounting. Experience; two years electrical contracting, and two years sales and production analysis in manufacturing corporation. Location preferred, Ohio or vicinity. B-9865.

CHIEF, SUPERVISING, OR CONSULTING ENGINEER, thirty-five years mechanical and electrical engineering; electric railways, public utilities, engineering and industrial companies; planning and execution several steam railroad electrifications; rehabilitation steam plants; chemical process development; public utility valuations and economic reports; electrolysis; research; power transmission. Railway or industrial engineering preferred. Available soon. Employed. B-3246.

POSITION DESIRED by recent E. E. graduate, with a small consulting firm in New York City. Has design and construction experience. Married. C-1514.

ASSISTANT ELECTRICAL ENGINEER, 29, married, E. E. degree, eighteen months General Electric test, three years electrician and foreman on industrial construction, two and one-half years public utility construction engineering and testing on generating stations, substations and large customers. Location preferred, East, but not essential. Available on two weeks' notice. Present salary $3000. B-7637.

ELECTRICAL ENGINEERING GRADUATE, 24, single, with four and one-half years' experience in design and operation of electrical distribution and transmission systems and equipment. Location preferred, East. C-1925.

ENGINEER, 30, single, graduate mechanical engineer, two years General Electric test, power plant experience and combustion tests, desires sales or executive work. Location preferred, New York and vicinity. C-729.

ELECTRICAL ENGINEER, single, young electrical engineering graduate, technically trained in experimental physical work, desires part time work with some local New York firm along research lines. At present studying law to obtain patent training, etc. Also open to patent-law office. Location preferred, New York City. C-1969.

RECENT GRADUATE-JUNIOR ENGINEER, 22, single, recent college graduate, B. S. degree in Electrical Engineering, knowledge of civil engineering, some electrical railroad experience. Location preferred, New England. C-2168.

JUNIOR ENGINEER, 25, single, graduate E. E., four years' experience; G. E. test, public utility construction and repairs, instructor in engineering college, economic selection and general engineering studies. Employed at present, but desires new connection. Location preferred, East. C-2347.

RECENT GRADUATE, 26, single, engineering graduate (M. S. 1925), specialized in electrical and hydro-electric engineering. One year research assistant in hydraulics, and one year part time correcting papers in correspondence school. Desires connection with utilities or factories, or assistant hydraulic instructor. Location preferred, anywhere in United States. C-2480.

ELECTRICAL ENGINEER, 30, single, graduated from Massachusetts Institute of Technology in 1923, B. S. in Electrical Engineering, general electrical engineering experience since then, including nearly two years teaching in E. E. at the University of Pennsylvania. Wishes sales promotion or engineering work. C-2481.

PHYSICIST, 36, single, Ph. D. in June, four years university instructor, four years Bureau of Standards and industrial research, low temperatures and pyrometry, electrical standards, electrochemistry, optical design. Thorough mathematician, several published papers. Research or teaching. Available in June. C-2588.

ELECTRICAL ENGINEER, 27, single, technical graduate, A. B., E. E. 1926, desires position in any branch of electrical engineering. Previous experience in telephone and radio communication. Familiar with Spanish, French and Italian. Available at once. Location preferred, New York City and vicinity. C-2638.

ENGINEER, expert at utilization of spare electric power for steam generation (electric boilers), furnaces and industrial purposes generally, wishes permanent or temporary connection. Is also well trained in power house and substation design, construction and equipment, and experienced in inventory, pricing, valuation and general company work. B-8863.

ELECTRICAL ENGINEER, with wide and thorough experience in America and Europe, desires position as executive or chief electrical engineer. Competent in electrical and mechanical design of electrical machinery; made special study of gasoline-electric automotive vehicles. Familiar with research work in electrical, mechanical and physical problems. Location preferred, East. Minimum salary $6600. C-693.

ELECTRICAL ENGINEER, 31, married, experienced in the electrical design of power plants, sub-stations, transmission lines, special studies, investigations, reports, etc. Technical graduate, business training. Will consider a connection with a consulting organization, or an operating company. Location preferred, Chicago. C-995-597.

GRADUATE ELECTRICAL ENGINEER, now employed, desires to connect with industrial plant to take charge of operation and maintenance, or with operating company to take charge of plant operation. Eight years' experience with General Electric Company, and eight years' experience as power, transmission and maintenance engineer for large concern generating their own power. Available in thirty days. C-2584.

MANAGER, 37, married, redesign machinery and processes, origination new products; installation new departments; purchase new businesses; installation shop control; sixteen years' experience large and moderate sized manufacturing plants. Graduate engineer. Location preferred, Milwaukee, Wisconsin. C-1050.

ELECTRICAL ENGINEER, 36, married, broad experience in original development and design of electrical apparatus. More than ordinary technical knowledge and ability to use it, combined with executive and sound business ability. Will consider any location. C-1181.

SUPERINTENDENT OF POWER, electrical engineer, with twelve years' experience steam power plants and electrical generating stations. Construction, operation, maintenance. Speaks Spanish. Location preferably foreign. C-1372.

ENGINEER, electrical and mechanical, 38, married, desires executive position. Experienced as manager and chief engineer in all branches of machinery manufacturing including production. Location, New England. C-1388.

EXECUTIVE ENGINEER, ELECTRICAL ENGINEER, OR MAINTENANCE ENGINEER, electrical engineer with fourteen years' central station and engineering experience,

supplemented by consulting, construction and State Public Service Commission engineering work. Can win and hold the public's confidence, and handle others efficiently and quietly. 42. Location preferred, United States. C-1509.

SALES EXECUTIVE, 39, married, graduate engineer with proven capabilities, well seasoned by unique experience and training in production, distribution, selling and organization work. Understands merchandising, market analysis, and promotion planning. Personality, appearance and character command respect and inspire confidence. Desires responsible position in a sales organization. Location not restricted. C-1781.

DIVISION ELECTRICAL ENGINEER, 32, married, branch superintendency or manager of local enterprise calling for exercise of initiative, tact and decision, is sought by graduate E. E. whose present responsibility for the construction, operation and maintenance of several electrified coal mines brings him in intimate contact with lines, machinery, men, and other companies. Location dependent upon salary and opportunity. C-1828.

ELECTRICAL ENGINEER, 33, married, eight years' experience in the electrical engineering field since graduation, consisting of one year steel mill experience on electrical applications and equipment, three years telephone engineering and design of protective apparatus for telephone and telegraph systems, nearly five years design of controlling equipment and apparatus and application of control for industrial and special applications. Executive ability, accustomed to assuming responsibility. Good record and references. At present employed. Location preferred, East. C-1864.

ELECTRICAL ENGINEER, 43, married, with broad experience in agriculture, electrical industry, and utility; inventive and resourceful, desires to affiliate with an aggressive utility company in the capacity of service engineer and the development of agricultural applications of electric power. Location preferred, East. C-1867.

ELECTRICAL ENGINEER, 32, married, four years' experience in steam power plant work with large corporation. Plant engineer, supervision tramway, construction substation, installation of 3500 kw. G. E. turbine are included in my experiences. Location preferred, South. C-2001.

ELECTRICAL ENGINEER, 42, married, graduate of University of Illinois and University of California in electrical engineering, twelve years' experience in engineering instruction and administration. In two state colleges has become head of E. E. departments. Four years' outside engineering experience. C-2155.

ASSISTANT DISTRIBUTION ENGINEER, 25, single, graduate E. E., three and one-half year's experience in electric distribution department of utility company making construction and material specifications, also layout and practical field experience and testing of material. Desires a responsible position with an opportunity for expanding. Location preferred, East. C-2199.

EXECUTIVE, 34, married, with a business and engineering training, together with ten years of successful engineering and construction experience in the mining, water supply, oil field, oil refinery, and hydro-electric fields available. Location preferred, Pacific Coast. C-2206-11-A-17.

GRADUATE ELECTRICAL ENGINEER, age 28, single, G. E. test, inspection and test of automatic telephone equipment, maintenance engineering problems, supervision of installation various types electrical machines, design lighting systems, and indoor, outdoor, substations; desires responsible position with firm or public utility in construction of transmission projects or hydro electric developments. Available now. C-2268.

ELECTRICAL ENGINEER, A. I. E. E., 35, married, 15 years' experience, experienced in corporation executive work, purchasing electrical equipment, industrial sales engineering, electrical, mechanical, civil engineering construction, experienced in handling both office and field force. Available month's notice. Location preferred, vicinity New York. C-2346.

MANUFACTURING EXECUTIVE OR TECHNICAL ADVISER TO BANKING INTEREST, A. S. M. E., A. I. E. E., 43, married, with broad engineering, commercial sales, manufacturing and executive experience. Demonstrated practical vision and inventive ability for developing new equipment and production methods for reducing cost and uses for waste products. East preferred. Permanent or consulting work. C-2406.

EXECUTIVE, A. I. E. E., 28, single, assistant general manager of small electrical manufacturer seeks wider field and broader opportunity. Westinghouse student course, sales experience. At present assisting in general management, charge all sales correspondence and closing important contracts. Location, no preference. C-2469.

CHEMICAL ELECTRICAL ENGINEER, A. I. E. E., 33, married, chemical engineer with extensive electrical experience and record of designing and developmental abilities. Experienced in conduct and direction of research and possesses the engineering viewpoint and experience necessary to successfully commercialize the results of research. Location desired, United States or Canada. C-2530.

ELECTRICAL ENGINEER OR DESIGNER, A. I. E. E., 40, married, twenty years' experience; technical, practical, executive; in design, construction, operation, public relations, etc., with various public utilities. Position with combination of these features desired. Location preferred, New York State, Pennsylvania or Middlewest. C-2647.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MARCH 25, 1927

ACHENBACH, CHARLES H., Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

*ALLAN, JOHN CHARLES, Transformer Design Dept., Canadian General Electric Co., Lansdowne Ave., Toronto, Ont., Can.

ALRICH, EUGENE WOODFORD, Electrical Engineer, General Electric Co., Schenectady, N. Y.

*ANDREAE, STEPHEN CARL, Estimating Engineer, Wisconsin Electric Mfg. Co., 1031 Clybourn St., Milwaukee, Wis.

ARGUIMBAU, FRANCISCO, Representative, "Compania Hispano Americano de Electricidad" of Barcelona, Spain; for mail, 146 W. 82nd St., New York, N. Y.

ARROUET, MARCEL, Engineer, Ste. Metallurgique de Montricher, Paris, France; for mail, 103 Waverly Place, New York, N. Y.

ATKINS, JAMES GEORGE, Lieut., U. S. Navy, Assistant Inspector of Machinery, U. S. N.; Bethlehem Shipbuilding Corp., Quincy, Mass.

*BABBIT, FREDERIC MARTIN, Construction Department, West Penn Power Co., Uniontown, Pa.

BARBERA, ARTHUR A., Electrical & Sales Engineer, 502 Delta Bldg., Los Angeles, Calif.

BARRETT, EDW. C., Telephone Engineer, Chesapeake & Potomac Telephone Co., 725 13th St., N. W., Washington, D. C.

BAXTER, WALLACE J. F., Assistant Engineer, Hydro-Electric Power Commission, 190 University Ave., Toronto 2, Ont., Can.

BESCOBY, FREDERICK ERNEST, 2nd Engineer, British Columbia Electric Railway Co., Steam Plant, Union St., Vancouver, B. C., Can.

BEWLEY, LOYAL VIVIAN, Engineer, General Electric Co., Pittsfield, Mass.

BLOCH, IVAN, Draftsman, Survey Bureau, Dist. & Inst. Dept., New York Edison Co., 41st St. & 1st Ave., New York, N. Y.

*BORGESON, CARL ANDERS, Technical Employee, American Tel. & Tel. Co., 311 W. Washington St., Chicago, Ill.

BORUSZAK, NATHAN, Electrical Engineer, F. A. Vaughn, Inc., 467 Jackson St., Milwaukee, Wis.

BOYLE, WILLIAM EDWARD, Engineer, High Voltage Underground Research, Rome Wire Co., Rome, N. Y.; for mail, 640 Harvard Ave., Montreal, P. Q., Can.

BRADLEY, HORACE ELLSWORTH, Foreman, Meter Laboratory, Potomac Electric Power Co., 14th & C Sts., N. W., Washington, D. C.

BRENNAN, WILLIAM WILSON, Distribution Dept. Assistant, Edison Electric Illuminating Co. of Brockton, 76 School St., Brockton, Mass.

BRICKSON, HERBERT O., Radio Engineer, Wisconsin Dept. of Markets, Stevens Point, Wis.

*BROADWELL, EMERSON, Testing Dept., General Electric Co., Schenectady, N. Y.

*BROWN, ERNEST EMBICH, Electrical Estimator, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia; res., West Philadelphia, Pa.

BROWN, FRED HENRY, Electrical Foreman, Power Department, Denver Tramway Corporation, Power House, 14th & Platte Sts., Denver, Colo.

CARLIN, FRANCIS MARION, Division Supervisor of Supplies & Special Studies, Western Electric Co., Inc., 1312 Arch St., Philadelphia, Pa.

CARLSON, PARLEY EDWARD, General Wire Chief, Postal Telegraph-Cable Co., 1005 Postal Telegraph Bldg., 140 W. Van Buren St., Chicago, Ill.

CASE, NEWTON GILES, Meter Foreman, The Syracuse Lighting Co., Inc., 431 Fulton St., Syracuse; res., Marcellus, N. Y.

CHARLTON, HOWARD CUNNINGHAM, Engineer, A. Reyrolle & Co., Ltd., Royal Bank Bldg., Toronto 2, Ont., Can.

CHRISTIANSEN, PETER LAURITS, Electrical Engineer, West Indian Co., Ltd., St. Thomas, Virgin Islands, U. S. A.

CLEMENT, ALBERT EDWARD, Electrician & Meterman, Natrona Light & Power Co., Natrona, Pa.

*COCHRAN, WILLIAM HENRY, Welding Engineer, General Electric Co., General Superintendent's Office, East Lake Road, Erie, Pa.

*CODD, W. ALFRED, Instructor in Electrical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

CONRAD, A. G., Assistant Instructor, Electrical Engineering Dept., Ohio State University, Columbus, Ohio.

*COOK, VEAZEY MONROE, Engineering Assistant, United Electric Light & Power Co., 56 Cooper Sq., New York, N. Y.

COSTELLO, JOHN M., District Manager, Livingston-Niagara Power Co., Syracuse, N. Y.
CRAMER, CLIFFORD HILL, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York; res., Little Neck, N. Y.
CROM, GEORGE CURTIS, Jr., Research Engineer, American Transformer Co., 178 Emmet St., Newark; res., East Orange, N. J.
CROSBY, PAUL WATT, Design Div., Trans. & Dist. Dept., Philadelphia Electric Co., 23rd & Market Sts., Philadelphia; res., Swarthmore, Pa.
*CROSBY, ROY HENRY, Student, University of Washington, Seattle, Wash.
CUMMINGS, CLESSON SEYMOUR, Electrical Engineer, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
*DANIELS, JOHN SHULL, Engineer, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco, Calif.
DATT, MUNISHWAR, International Harvester Co., 2600 W. 31st St., Chicago, Ill.
DI LUCCI, ANTONIO, Electrical Engineer, Victor X-Ray Corporation, 2012 Jackson Blvd., Chicago, Ill.
DI TOMMASO, JOHN, Draftsman, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
DOW, IRVING M., Assistant Chief Draftsman, Chesapeake & Potomac Telephone Co., 725 13th St., N. W., Washington, D. C.
*EATON, JAMES ROBERT, Transmission Line Engineer, Consumers Power Co., 244 Michigan Ave. West, Jackson, Mich.
EVANS, CARL W., System Dispatcher, San Antonio Public Service Co., San Antonio, Texas.
EVANS, GEORGE TREWATHA, Laboratory Helper, Public Service Electric & Gas Co. of New Jersey, 21st St. & Clinton Ave., Irvington; res., Bogota, N. J.
FAESI, HERMAN A., Electrical Engineer, American Brown Boveri Electric Corporation, Camden, N. J.
FAY, OWEN JAMES, Engineer, Western Electric Co., Inc., Hawthorne Station, Chicago, Ill.
FLETCHER, WILLARD TOWNSEND, Supervisor, Plant Dept., Western Union Telegraph Co., 195 Broadway, New York, N. Y.
*FORMOSA F., JOSE, Assistant Engineer of Construction, Mexican Light & Power Co., Gante 20, Mexico, D. F., Mex.
FOYE, JOHN FRANCIS, Maintenance Electrician & Plant Mechanic, Blue Diamond Building Materials Co., Commercial St. Extension, Malden; res., Roxbury, Boston, Mass.
GAERTNER, ARTHUR H., Electrician, Construction Dept., Commonwealth Edison Co., Northwest Generating Sta., California & Roscoe Sts., Chicago, Ill.
GERBER, HAROLD L., Electrical Inspector, Dept. of Electricity, City Hall, San Francisco, Calif.
*GLUCKMAN, MANUEL, Cable Dispatcher, Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.
GOLDING, CHARLES CARL, Assistant Operator, New York Edison Co., 27 W. 16th St., New York, N. Y.
*GRABAR, JOHN, Engineer, Technical Editor, M. B. Sleeper, Inc., Radio Hill, Poughkeepsie; res., New York, N. Y.
*GREINER, ARTHUR M., Chief Electrician, Brandes Products Corporation, 200 Mt. Pleasant St., Newark; res., Jersey City, N. J.
GRIFFIN, BENTON FRANCIS, Electrician, Staff Electric Co., 586 Jackson St., Milwaukee; res., Wauwatosa, Wis.
GROTHE, ALBERT F., Instructor, Call & Key Indicator School, Plant Maintenance Dept., Ohio Bell Tel. Co., Electric Bldg., Cleveland, Ohio.
*GRUNDEL, WILLARD W., Salesman, Electric Storage Battery Co., 6150 Third St., San Francisco, Calif.
GRUNENTHAL, CHARLES J., Tester, New York Edison Co., 92 Vandam St., New York, N. Y.
HALEY, WILLIAM, Electrician, Public Service Gas & Electric Co., Newark; res., Jersey City, N. J.
HALL, OLIVER C., Technical Employee, Long Lines Dept., American Tel. & Tel. Co., 15 Dey St., New York, N. Y.
HAMMERLE, FRANKLIN LUTHER J., Assistant Meter Engineer, Syracuse Lighting Co., Inc., 431 Fulton St., Syracuse, N. Y.
HANFORD, R. E., Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
HARPER, EDWARD E., Electrician, Madison Coal Corp., Glen Carbon; res., East St. Louis, Ill.
HELLER, PAUL E., Draftsman, New York Edison Co., 44 E. 23rd St., New York, N. Y.
HINTERMANN, JACOB, Sponsor Engineer, Station Design Section, Duquesne Light Co., 435 6th Ave., Pittsburgh; res., Swissvale, Pa.
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JACKSON, WILLIAM GRAHAM, Assistant Electrical Engineer, Hamilton Hydro-Electric System, 12 King St. E., Hamilton, Ont., Can.
JOHNSON, HAROLD L., Central Office Engineer, Western Electric Co., 100 Central Ave., Kearny; res., Jersey City, N. J.
*KEANE, ROBERT LOUIS, Special Tester, Philadelphia Electric Co., 2301 Market St., Philadelphia; res., Overbrook, Philadelphia, Pa.
KENNEDY, WILLIAM PENDLETON, Chief Operator, Virginia Electric & Power Co., Reeves Ave., Norfolk, Va.
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*KERSEY, WYATT DENDY, Sales Engineer, Hazard Mfg. Co., 938 Brown Marx Bldg., Birmingham, Ala.; res., Kathleen, Ga.
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LAMBERT, LEROY S., Assistant to President, Northwestern Bell Tel. Co., Telephone Bldg., Omaha, Nebr.
LARSSON, ERIK, Draftsman, Electrical Dept., The Koppers Co., Union Trust Bldg., Pittsburgh, Pa.
LAUBSCHER, WILLIAM FLETCHER, Junior Engineer, Monongahela West Penn Public Service Co., 504 Bethlehem Bldg., Fairmont, West Va.
*LAW, JOHN CARL, Draftsman, Bessemer & Lake Erie Railroad, Bessemer Bldg., Greenville, Pa.
LEACH, HERBERT J., Jr., Electrical Engineer & Supt., Brown & Caine, 2317 Calumet Ave., Chicago, Ill.
LEVIN, SAMUEL A., Assistant Engineer, Engineering Dept., N. E. L. A., 37 W. 39th St., New York, N. Y.
*LINVILLE, THOMAS MERRIAM, Electrical Engineer, General Electric Co., Pittsfield, Mass.
LITHGOW, ELLIS DAVID, Test Floor Work, Allen-Bradley Co., 286 Greenfield Ave., Milwaukee, Wis.
LONG, ROBERT JAMES, Jr., Engineering Assistant, Public Service Production Co., 15 East Park St., Newark, N. J.
LUCIER, OLIVER A., Generating & Substation Operator, Eastern Connecticut Power Co., 362 Main St., Norwich; res., Baltic, Conn.
LYONS, FRANCIS EDWARD, Overhead Lines Dept., Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
LYONS, RICHARD DUNKLEE, Testing Dept., General Electric Co., Schenectady; res., Scotia, N. Y.
LYTLE, JAMES RICHARDSON, Laboratory Assistant, Public Service Electric & Gas Co., Metuchen, N. J.; res., Brooklyn, N. Y.
MALMROS, WALTER T., Construction Supt., Public Service Production Co., 15 E. Park St., Newark, N. J.
MALONE, WILLIAM F., Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Paterson, N. J.
MANSFIELD, WILLIAM HENRY, Division Plant Engineer, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
*MARTINE, CHESTER EARL, Test Engg., Installation Dept., Western Electric Co., Inc., 149 Fulton St., New York, N. Y.; res., Upper Montclair, N. J.
MAY, ALBERT, Telephone Engineer, Chesapeake & Potomac Telephone Co., 725 13th St., N. W., Washington, D. C.
McCARTNEY, CHARLES EUGENE, Engineer, Southern Cities Power Co., Shelbyville, Tenn.
McCORMACK, ELIOT, Junior Engineer, New York & Queens Electric Light & Power Co., Lawrence & Amity Sts., Flushing; res., Jamaica, N. Y.
McCUTCHEN, FRANK L., Master Mechanic, Monsanto Chemical Works, Mississippi & Prardise Aves., East St. Louis, Ill.
MELVILLE, JOHN, Chief Engineer, British Columbia Electric Railway, Steam Plant, Carrall St., Vancouver, B. C., Can.
MICHAELS, A. P., General Manager, Orlando Utilities Commission, Orlando, Fla.
*MILLER, DALTON WALTER, Engineer, Transmission Dept., Pacific Tel. & Tel. Co., 15 N. Park St., Portland, Ore.
MILLER, RALPH HUTCHINSON, Member of Technical Staff, Bell Telephone Laboratories Inc., 463 West St., New York; res., Lynbrook, N. Y.
MITCHELL, JOSEPH P., Sales Engineer, Murray Conduit Systems, 55 Duane St., New York, N. Y.
MORTON, WILLIAM IRA, Electrical Draftsman, Lehigh Portland Cement Co., 719 Hamilton St., Allentown, Pa.
NAHAPIET, ERNEST OWEN, Test Man, General Electric Co., Schenectady, N. Y.
NAUDAIN, CRAIG TICHENOR, Senior Inside Man, New York Telephone Co., 34 Engle St., Englewood, N. J.
NELSON, EARL PIERCE, Designing Engineer, Direct Current Engg. Dept., General Electric Co., 1 River Road, Schenectady, N. Y.
NEU, MAX I., Electrical Engineer, 44 Whitehall St., New York, N. Y.
NOLL, ELMER JOHN, Foreman, General Electric Co., 429 N. 7th St., Philadelphia, Pa.
NUKUSHINA, RINJI, Chief Electrical Engineer, Kanto Hydro-Electric Power Co., Tokyo Kaijo Bldg., Marunouchi, Tokyo, Japan; for mail, Asano Bussan Co., 165 Broadway, New York, N. Y.
*NUTTING, D. C., Light Dept., City of Tacoma, Tacoma, Wash.
O'BRIEN, FREDERIC L., Engineer, Research Dept., Western Union Telegraph Co., 195 Broadway, New York, N. Y.

*OEHLER, JOHN FREDERICK, Elec. Dept., Bethlehem Steel Co., Lackawanna; res., Buffalo, N. Y.
OLSEN, ARTHUR CHARLES, Supt., Coast Stations, Independent Wireless Telegraph Co., Inc., 67 Wall St., New York.
OLSEN, BERNHARD, Manager, General Electric Co., Paulsen Bldg., Spokane, Wash.
ORR, JIM J., Electrical Engineer, Pontiac Plant, Oakland Motor Car Co., Pontiac, Mich.
*PARRIS, THOMAS, Jr., Assistant Electrical Designer, Philadelphia Electric Co., 1035 Chestnut St., Philadelphia; res., Germantown, Philadelphia, Pa.
PARRY, GRANT, System Dispatcher, Penn-New Jersey Power System; for mail, Metropolitan Edison Co., 141 S. 7th St., Reading, Pa.
PARTZ, VICTOR A., Consulting Electrical Engineer & Associate Instructor, American School of Correspondence, 58th & Drexel Ave., Chicago, Ill.
*PATTERSON, J. C., Jr., Assistant Relay Engineer, Appalachian Electric Power Co., Huntington, West Va.
PETTIBONE, THEODORE MAXWELL, Distribution Electrical Engineering Dept., Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
PHILLIPS, WILLIAM ALBERT, Foreman, Meter Laboratory, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.
PITTMAN, DAIL, Salesman, Wagner Electric Corporation, 3029 Locust St., St. Louis, Mo.
PLATTO, LEWIS FREDERICK, Shop Foreman, Meter Dept., Syracuse Lighting Co., Inc., 431 Fulton St., Syracuse; res., Brewerton, N. Y.
PLIEGO, ANTONIO, Jr., Electrical Engineer, Mexican Light & Power Co., Gante 20, Mexico, D. F.; res., Tacubaya, D. F., Mex.
POLING, C. VINNEDGE, Electrical Engineer, Commonwealth Power Corporation, Jackson, Mich.
POPE, HAROLD T., Meterman, Niagara, Lockport & Ontario Power Co., Syracuse; res., Weedsport, N. Y.
POWERS, THOMAS N., Traffic Manager, Postal Telegraph-Cable Co., Postal Telegraph Bldg., 253 Broadway, New York, N. Y.
*PRICE, GORDON FIELD, Engineer, Southeastern Underwriters Association, Atlanta, Ga.
REARDEN, ROBERT A., Assistant to Engineer of Meters, Relays and Automatic Substations, Columbus Railway, Power & Light Co., Gay St. Sta., Columbus, Ohio.
REINHARD, AUGUST J., Engineer, Western Union Telegraph Co., 195 Broadway, New York; res., Brooklyn, N. Y.
RHINEHART, ROBERT JARVIS, Electrical Engineer, Arkansas Power & Light Co., Pine Bluff, Ark.
ROEHRIG, GEORGE JOSEPH, Meter Engineer, Syracuse Lighting Co., Inc., 431 Fulton St., Syracuse, N. Y.
RUBIN, BERNARD WILLIAM, Illuminating Engineer, B. B. T. Corp. of America, Atlantic Bldg., Philadelphia, Pa.; res., New York, N. Y.
RUDD, E. LYNN, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*SAMSON, HECTOR BRADFORD, Inspector, Electrical Dept., Glen Alden Coal Co., Scranton; res., Dunmore, Pa.
SAUL, GEORGE NATHAN, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*SCHAEFER, ANTON HENRY, Assistant, Dept. of Electrical Engineering, University of California, Berkeley; for mail, San Francisco, Calif.
*SCHAFER, ARTHUR HENRY, Estimator, Safety Wire & Cable Mfg. Co., 114 Liberty St., New York; res., Richmond Hill, N. Y.
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SCHWORER, WILLIAM JOSEPH, Shift Operator, Big Creek Plant No. 1, Southern California Edison Co., Big Creek, Calif.
SEYMOUR, ROBERT WILLIAM, Sales Engineer, Electric Storage Battery Co., Peachtree & Baker Sts., Atlanta, Ga.
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SMITH, J. EDMUND, Assistant Supt., Electric Distribution, Rockland Light & Power Co., 12 N. Broadway, Nyack, N. Y.
SMITH, JOE BELTON, Assistant Division Supt. of Construction, Dixie Construction Co., Birmingham, Ala.
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*SVOBODA, CHARLES, Development Engineer, Western Electric Co., Hawthorne Station, Chicago; res., Clarendon Hills, Ill.
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*TELLEZ, JORGE SERGIO, Construction Dept., Electrical Div., Detroit Edison Co., Detroit; for mail, Ann Arbor, Mich.
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*TREVINO, RODOLFO R., Auxiliary Engineer, Plant Dept., Mexican Tel. & Tel. Co., Tampico, Tamps, Mex.
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VENKATESWARAN, P. S., Statistician, Tata Hydro-Electric Power Supply Co., Ltd.; Andhra Valley P. S. Co., Ltd., Tulsi Pipe Line Road, De Lisle Road P. O., Bombay, India.
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*WALSH, HAROLD EDGAR, Junior Radio Electrical Engineer, Civil Service of Canada, 299 Wellington St., Ottawa, Ont., Can.
*WALTER, GEORGE FRED, Assistant Electrical Division Chief, Testing Laboratory, Public Service Electric & Gas Co., Irvington; res., Hilton, N. J.
WALTHER, LEE, 142 St. Pauls Place, Brooklyn, N. Y.
WEEDEN, EDWARD H., Consulting Engineer, International General Electric Co., Schenectady, N. Y.; Professor, Mackenzie College, Rua Maria Antonia 79, Sao Paulo, Brazil, So. Amer.
WELCH, JOHN LEO, Foreman, U. G. I. Contracting Co., 463 Fulton St., Syracuse, N. Y.
*WELLS, WILLIAM BRUCE, Examiner, Board of Fire Underwriters of the Pacific, Merchants Exchange Bldg., San Francisco, Calif.
WELMAN, GEO., Chief Electrical Inspector, Louisiana Rating & Fire Prevention Bureau, 346 Camp St., New Orleans, La.
WELSH, CHARLES JOSEPH, Designer, Philadelphia Electric Co., 902 Chestnut St., Philadelphia, Pa.
WERNER, DAVID THOMAS, Sales Engineer, Anaconda Copper Mining Co.; for mail, American Brass Co., Technical Dept., Waterbury, Conn.
*WETHERILL, LYNN, Engineer, General Electric Co., Schenectady, N. Y.
WHETSTONE, STANLEY LEROY, Engineering Assistant, Public Service Production Co. Street Dept., 15 E. Park St., Newark, N. J,
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WILSON, RICHARD I., Underground A. C. & Arc Lines Dept., Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.
WITHERS, LESTER FRANK, Testing Engineer, Lake Coleridge Power Scheme, Addington, N. Z.
*WOLLASTON, FRANCIS OTTLY, Junior Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
WOOD, HAROLD OKELL, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

WOODARD, JOHN WILSON, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
Total 198.
*Formerly enrolled students.

ASSOCIATES REELECTED MARCH 25, 1927

BARTON, LOWRIE CHILDS, Manager, Central Station Division, Westinghouse Elec. & Mfg. Co., 201 W. Third St., Cincinnati, Ohio.
BEILER, ALBERT HENRY, American Gas & Electric Co., 30 Church St., New York, N. Y.
EARLE, RALPH H., Estimating Engineer, Hydraulic Turbine Dept., Allis-Chalmers Mfg. Co., Milwaukee; res., Wauwatosa, Wis.
GLAZE, HENRY C., District Manager, Industrial & Railway Dept., Rocky Mountain Dist., General Electric Co., Security Bldg., Denver, Colo.
MOSHER, S. H., Supervisor of Overhead & Underground Construction, Public Service Co. of Northern Illinois, 72 W. Adams St., Chicago, Ill.
WOODWARD, JOHN G., Substation Operator, Bureau of Power & Light, Los Angeles, Calif.

ASSOCIATE REINSTATED MARCH 25, 1927

PERRY, ALEXANDER, Vice-President, Monry Engineering Co., 500 Fifth Ave., New York, N. Y.

MEMBERS ELECTED MARCH 25, 1927

ANDERSON, HALLAM HANS, Engineer; Production Dept., Shell Co. of California, 410 Higgins Bldg., Los Angeles, Calif.
CLENDENING, CLAIR ADDISON, Commissioner, Manitoba Power Commission, 44 Parliament Bldgs., Winnipeg, Man., Can.
HORINE, KARL, Research Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
KLINE, CONRAD W., Chief Engineer, Harding Cream Co., 802-12 Harney St., Omaha, Nebr.
LELAND, C. A., JR., Assistant General Manager & Chief Engineer, Kansas Power & Light Co., Topeka, Kans.

TRANSFERRED TO GRADE OF MEMBER MARCH 25, 1927

AHUJA, D. C., Asst. Chief Electrical Engineer, Tata Iron & Steel Co., Ltd., Jamshedpur, India.
ALLCOCK, HARRY, Export Manager, W. T. Glover & Co. Ltd., London, England.
BEERY, EARL J., Assistant to General Superintendent of Power, Puget Sound Power & Light Company, Seattle, Wash.
HARVEY, R. J., Consulting Engineer to New Zealand Government, London, England
MACKNESS, CYRIL F., Consulting & Inspecting Engineer, London, England.
NOTTORF, WILLIAM E. A., Assistant to Executive Vice-President, Automatic Electric Inc., Chicago, Ill.
TANABE, STETFAN, Meter Design Engineer, Tokyo Electric Co., Kawasaki, Japan.
WELKE, RUDOLPH A., Professional Electrical Engineer, Adlanco Industrial Products Corp., New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held March 15, 1927, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary

To Grade of Fellow

DOYLE, EDGAR D., Electrical Engineer, Leeds & Northrup Co., Philadelphia, Pa.
HOLCOMBE, ERNEST S., Electrical Construction Engineer, Interborough Rapid Transit Co., New York, N. Y.
KRUM, HOWARD L., Vice President, Morkrum-Kleinschmidt Corp., Chicago, Ill.
MAXFIELD, JOSEPH P., Manager of Development and Research, Victor Talking Machine Co., Camden, N. J.
MEYER, EDWARD B., Chief Engineer, Public Service Production Co., Newark, N. J.
OWENS, JAMES W., Director of Welding, Newport News Shipbuilding & Dry Dock Co., Newport News, Va.
WISEMAN, ROBERT J., Research Engineer, The Okonite Company and The Okonite-Callender Cable Co., Inc., Passaic, N. J.

To Grade of Member

ANDREWS, FRANCIS E., Engineer, Electrical Transmission Design, Public Service Co. of No. Illinois, Chicago, Ill.
BAKER, DOUGLAS BROOKS, Vice President and General Manager, Standard Electrica, S. A. Madrid, Spain.
BENDER, LOUIS B., Signal Officer, 9th Corps Area, U. S. Army, The Presidio of San Francisco, Calif.
BEUGLER, HUGH M., Consulting Engineer, 50 Market St., Poughkeepsie, N. Y.
BLOOMFIELD, JAMES M., Supt., Light and Power Plant, Kamsack, Sask., Canada.
BOORZHINSKY, NICHOLAS P., Electrical Engineer, Transformer Engg. Dept., General Electric Co., Pittsfield, Mass.
CURTIS, HARRY A., Chief Engineer and General Manager, Hydro Electric Dept., Hobart, Tasmania.
CUSHING, RICHARD W., Electrical Engineer, Federal Power Commission, Washington, D. C.
DEANE, L. EARL, Engineer, American Presbyterian Mission, Metet par Yaounde, Cameroun, West Africa.
FORMAN, ALEXANDER H., Professor and Head of Department, West Virginia University, Morgantown, W. Va.
FRASER, WILLIAM W., Patent Attorney, Mayer, Warfield & Watson, New York, N. Y.
GRAHAM, SIMEON BURR, Engineering Department, American Tel. & Tel. Co., New York, N. Y.
GUILD, EARL S., Electrical Engineer, Carleton Mace Engg. Corp., Boston, Mass.
HALLORAN, HARRY R., Consulting Engineer, National Electrical & Engg. Company, Wellington, N. Z.
HARRISON, J. K. M., Owner, Harrison & Company, Engineers, Philadelphia, Pa.
HERTZ, STANTON S., Electrical Engineer, Copperweld Steel Co., New York, N. Y.
HOEPPNER, HENRY L., Assistant Electrical Engineer, Byllesby Engg. & Management Corp., Chicago, Ill.
KUHLMANN, JOHN H., Assistant Professor of Electrical Design, University of Minnesota, Minneapolis, Minn.
LUTHER, BENJAMIN S., Electrical Engineer, Stone & Webster, Inc., Boston, Mass.
MATTHEWS, THOMAS, Associate Professor of Electrical Engineering, University of Iowa, Iowa City, Iowa.
McNEILL, R. W., Electrical Engineer, Westinghouse E. & M. Co., East Pittsburgh, Pa.
NATHAN, EUGENE J., Toll Facilities Supervisor, Bell Telephone Company of Pa., Philadelphia, Pa.
PIERCE, PAUL H., Member of Technical Staff, Bell Telephone Laboratories, New York, N. Y.
STEVENS, FRANK J., Superintendent, Locke Insulator Corp., Victor, N. Y.
WEBER, RUDOLF L., Electrical Engineer, Stone & Webster, Inc., Boston, Mass.
WILLIAMS, EARL C., Electrical Engineer, Public Service Co. of No. Illinois, Chicago, Ill.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1927.

Anderson, O. M., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Angel, H., Western Union Telegraph Co., New York, N. Y.
Angus, D. G., Bell Telephone Laboratories, Inc., New York, N. Y.
Ankeney, F. N., Bell Telephone Co. of Pa., Philadelphia, Pa.
Applegate, G. M., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Arthur, E. S., New York Edison Co., New York, N. Y.
Auby, L. C., Illinois Power & Light Corp., St. Louis, Mo.
Berumen, J. A., 924 Morelos Ave., Torreon, Coah., Mex.
Birnie, J. Jr., Brooklyn Edison Co., Brooklyn, N. Y.
Blinn, E. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Boykin, R. E., Brooklyn Edison Co., Brooklyn, N. Y.
Browne, V. F., Boys Vocational School, Newark, N. J.
Brydon, E. K., Public Service Co. of No. Illinois, Oak Park, Ill.
Buddeke, V. F., Public Service Co. of No. Illinois, Chicago, Ill.
Bushby, M., Public Service Co. of No. Illinois, Joliet, Ill.
Buttolph, O. D., Western Electric Co., Chicago, Ill.
Callahan, M. E., Jr., General Electric Co., Salt Lake City, Utah
Campbell, R. M., Sangamo Electric Co., New York, N. Y.
Cannon, M. K., Jr., General Electric Co., Schenectady, N. Y.
Caswell, R. W., Public Service Co. of No. Illinois, Oak Park, Ill.
Chalupa, P. E., Duquesne Light Co., Pittsburgh, Pa.
Chamberlin, J. N., (Member), Pacific Tel. & Tel. Co., San Francisco, Calif.
Cheeseman, J. A., New York Telephone Co., Newark, N. J.
Cheney, F. C., Stone & Webster, Havre de Grace, Md.
Christen, V. E., Moloney Electric Co., St. Louis, Mo.
Cloyd, L. W., Southwestern Bell Telephone Co., St. Louis, Mo.
Corby, D. K., Public Service Co. of No. Illinois, Oak Park, Ill.
Cornelius, H. A., Public Service Co. of No. Illinois, Chicago, Ill.
Cox, R. C., Scranton Electric Co., Scranton, Pa.
Creasmon, W. E., Jr., Southern Bell Tel. & Tel. Co., York, S. C.
Deacon, L. O., Lincoln Meter Co. Ltd., Toronto, Ont., Can.
Dennis, J. H., Public Service Co. of No. Illinois, Joliet, Ill.
DeVoe, J. J., Board of Fire Underwriters of the Pacific, Los Angeles, Calif.
De Witt, J. H., JR., (Radio Transmitting Equipment,) Nashville, Tenn.
Dickey, A. W., Western Union Telegraph Co., New York, N. Y.
Dickey, W. E., City Elec. Supt., City of Revelstoke, Revelstoke, B. C., Can.
Dolder, A. J., 36 Wall St., New York, N. Y.
Dudley, W. A., (Member), Western Union Telegraph Co., New York, N. Y.
Earle, R. C., Brooklyn Edison Co., Brooklyn, N. Y.

Eddy, H. T., Public Service Co. of No. Illinois, Chicago, Ill.
Endress, G. E., Public Service Co. of No. Illinois, Joliet, Ill.
Ewart, W. E., Puget Sound Power & Light Co., Seattle, Wash.
Ewert, H. W., Northwestern Mfg. Co., Milwaukee, Wis.
Fernandes, J. A., Brooklyn Edison Co., Brooklyn, N.Y.
Fisher, F. E., Puget Sound Power & Light Co., Seattle, Wash.
Fletcher, B., New York Edison Co., New York, N.Y.
Flueler, A. K., American Brown Boveri Electric Corp., Camden, N.J.
Fonda, B. P., May Oil Burner Corp., Baltimore, Md.
Fort, T., Jr., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Foss, H. M., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Fouser, J. R., Public Service Co. of No. Illinois, Joliet, Ill.
Fox, C. E., General Electric Co., Schenectady, N.Y.
Frantz, J. D., General Electric Co., Portland, Ore.
Fraser, D. G., The Southern New England Tel. Co., New Haven, Conn.
Frisch, R. A., Public Service Laboratory, Irvington, N.J.
Gallo, C., Public Service Electric & Gas Co., Newark, N.J.
Geary, W. J. D., Pennsylvania Power & Light, Northampton, Pa.
Gideon, W. I., Virginia Public Service Co., Alexandria, Va.
Giger, W. A., American Brown-Boveri Electric Corp., Camden, N.J.
Gillespie, B. F., General Electric Co., Bloomfield, N.J.
Gorny, B. J., General Electric Co., Erie, Pa.
Grieb, V. J., General Electric Co., Erie, Pa.
Guildford, R. P., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Gunkel, E. H. R., (Member), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Guzzo, L. M., So. New England Telephone Co., Hartford, Conn.
Haas, C. H., (Member), Los Angeles City Schools, Los Angeles, Calif.
Halbach, R. H., Northwestern Mfg. Co., Milwaukee, Wis.
Hall, H. W., Pennsylvania Power & Light Co., Hazleton, Pa.
Harcus, W. C., Pacific Tel. & Tel. Co., San Francisco, Calif.
Hartay, C. E., Duquesne Light Co., Pittsburgh, Pa.
Harvey, J. O., Coast Counties Gas & Electric Co., San Francisco, Calif.
Hovey, L. M., Winnipeg Electric Co., Winnipeg, Man., Can.
Hudson, H. H., (Member), Electric Storage Battery Co., New York, N. Y.
Huntley, E. D., General Electric Co., Schenectady, N.Y.
Hurd, O. W., Northwestern Electric Co., Portland, Ore.
Hutmire, E. H., Tri-State College, Angola, Ind.
Iles, J. T., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Jacobsen, R. C., Edison Elec. Illuminating Co. of Brockton, Brockton, Mass.
Jones, H. K., Western Electric Co., Chicago, Ill.
Kellogg, R. B., Pacific Gas & Electric Co., San Francisco, Calif.
(Applicant for re-election.)
Keogh, R. J., Western Electric Co., Hawthorne, Ill.
Knobloch, E. S., Electrical Contracting, Erie, Pa.
Koester, H., N. Y. & Queens Elec. Light & Power Co., Flushing, N. Y.
Kraehm, C. E., General Electric Co., New York, N.Y.
Kunst, W. E., Public Service Co. of No. Illinois, Forest Park, Ill.
Lake, L. R., Roundout Paper Mills, Inc., Napanoch, N.Y.
Larkins, J. F., New York Telephone Co., New York, N.Y.
Larsen, S. P., Line Material Co., Portland, Ore.
Lauritsen, C. N., Public Service Co. of No. Illinois, Chicago, Ill.
LeBel, C. J., Mass. Institute of Technology, Cambridge, Mass.
Long, C. E., Puget Sound Power & Light Co., Wenatchee, Wash.
Luxem, E. J., Commonwealth Edison Co., Chicago, Ill.
MacFarlane, J. M., State Trade School, New Britain, Conn.
Mascharka, L. A., General Electric Co., Erie, Pa.
McAndrew, J. S., Jr., Brooklyn Edison Co., Brooklyn, N.Y.
McCann, E. E., Oregon Institute of Technology, Portland, Ore.
McClure, J. J., Western Electric Co., Chicago, Ill.
McClymont, H. R., (Member), Kerry & Chace, Ltd., Toronto, Ont., Can.
McDonald, I. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
McIntyre, M. V., Mountain States Tel. & Tel. Co., Helena, Mont.
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Nielsen, W. S., Trans-Lux Day Light Picture Screen, Inc., New York, N.Y.
Norling, B. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Norton, J. C., Pacific Gas & Electric Co., San Francisco, Calif.
Ogle, G. M., (Member), General Engg. & Management Corp., New York, N.Y.
Olsen, P., with Thos. E. Murray, New York, N.Y.
Olson, A. G., Public Service Co. of No. Illinois, Oak Park, Ill.
Ossin, J. S., General Electric Co., Pittsfield, Mass.
Pafenbach, W. M., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Palm, A. F., Western Union Telegraph Co., Salt Lake City, Utah
Park, C. M., Mutual Fire Prevention Bureau, Chicago, Ill.
Parker, A. L., City of Fort Worth Light Dept., Fort Worth, Texas
Patisteas, M. J. N., Stone & Webster, Boston, Mass.
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Pizzuti, F. D., Fordham Radio Laboratories, New York, N.Y.
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Powell, A. C., Bell Telephone Laboratories, Inc., New York, N.Y.
Prentiss, G. D., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Provan, J. C., Eagnier Fibre Products Co., Detroit, Mich.
Rector, C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Reis, A. J., Tri-State College, Angola, Ind.
Reynolds, S. S., New York Telephone Co., New York, N.Y.
Richman, S. L., Byllesby Engg. & Management Corp., Pittsburgh, Pa.
Robinson, C. A., General Electric Co., Schenectady, N.Y.
Rosengren, W. J., Western Electric Co., Kearny, N.J.
Ryan, D. C., United Fruit Co., Bocas del Toro, Panama
Rydzewski, J. H., General Electric Co., Erie, Pa.
Sadler, C. H., Tri-State College, Angola, Ind.
Salamon, M. A., General Electric Co., New York, N.Y.
Salvatore, M., The Baldwin Locomotive Works, Philadelphia, Pa.
Sasscer, C. D., General Electric Co., Schenectady, N.Y.
Sayre, G. B., Owen Dyneto Corp., Syracuse, N.Y
Seeley, E. S., Brooklyn Edison Co., Brooklyn, N.Y.
Shambeau, W. R., Shambeau Radio Studio, Oshkosh, Wis.
Shols, W. T., Public Service Co. of No. Illinois, Chicago, Ill.
Smith, E. J., American Bridge Co., Ambridge, Pa.
Smith, J. S., Brooklyn Edison Co., Brooklyn, N.Y.
Smith, M. B., Crouse Hinds Co., Syracuse, N.Y.
(Applicant for re-election.)
Spitzer, D., 320 E. 18th St., New York, N.Y.
Staples, E. I., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Starr, S. C., General Electric Co., Fort Wayne, Ind.
Stauffer, H. R., Metropolitan Edison Co., Reading, Pa.
Stecher, M. V., Western Union Telegraph Co., New York, N.Y.
Stedman, W. J., Judson Rolling Mills, Emeryville, Calif.
Stern, A. B., The Pacific Tel. & Tel. Co., Seattle, Wash.
Stewart, C. E., General Electric Co., Schenectady, N.Y.
Stewart, D. O., Manufacturer's Agent, St. Louis, Mo.
Stone, J. R., Bell Telephone Laboratories, Inc., New York, N.Y.
Svela, O. J., 410 Central Park West, New York, N.Y.
Swank, L. N., Elliott Co., Ridgway, Pa.
Sywulka, V. S., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Theroux, A. H., Salisbury Jenny, Inc., Providence, R.I.
Thompson, O. B., Electrician, Port of Seattle, Seattle, Wash.
Thowless, W. H., Barnet Leather Co., Little Falls, N.Y.
Thrasher, L. R., Garden City Irrigation Power Co., Garden City, Kans.
Timm, H. D., (Member), Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Tsoon, Z., Westinghouse Elec. & Mfg. Co., Wilkinsburg, Pa.
Twiss, R. H., General Electric Co., Schenectady, N.Y.
Vanderkodde, W. F., Public Service Co. of No. Illinois, Joliet, Ill.
Van der Voort, F. C., Electric Testing Laboratories, New York, N.Y.
Walter, A. P., McCormick Co., Baltimore, Md.
Weber, H. H., Rome Wire Co., Rome, N.Y.
Weiss, E. F., The Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Wells, J., Western Electric Co., Hawthorne, Ill.
Whitmore, P. H., Public Service Co. of No. Illinois, Evanston, Ill.
Whittingham, C. J., Brooklyn Edison Co., Brooklyn, N.Y.
Williams, G. J., Connecticut Light & Power Co., Waterbury, Conn.
Winchester, R. L., Illinois Power & Light Co., St. Louis, Mo.

Woodmore, F. L., Bethlehem Shipbuilding Corp., Quincy, Mass.
Wright, R. B., Electrical Products Corp., Oakland, Calif.
Yarrill, H. G., Ontario Hydro-Electric Commission, Niagara Falls, Ont., Can.
Zimmerman, G. G., Tri-State College, Angola, Ind.
Total 184

Foreign

Cameron, J. J. P., Chief Elec. Engr., Survey of Egypt, Giza, Muderich, Egypt
Kato, M., Hanshin Electric Railway Co., Amagasaki near Osaka, Japan
Pillai, K. T., Hydro-Elec. Engg., Madras Gov't., India; (For mail, Manchester, Eng.)
Schomaker, G. E., Automatic Telephones, Ltd., Sydney, N. S. W., Aust.
Shire, L. E., Andian National Corp., Ltd., Cartagena, Colombia, S. A.
Timms, M. C., (Member), Siemens Bros. & Co., Ltd., Woolwich, London, S. E., Eng.
Total 6

STUDENTS ENROLLED

Abramovitz, Abraham, Univ. of Pennsylvania
Adams, Arthur A., Ohio Northern University
Allen, M. Irving, Pennsylvania State College
Annis, Quincy M., Engg. School of Milwaukee
Anselm, Morris E., Mich. State College of Agr. & Applied Science
Arenberg, Ray D., Iowa State College
Artman, Noel G., Kansas State Agr. College
Ayers, Abner F., Virginia Polytechnic Institute
Banford, Mariner, University of Utah
Barlow, Erle P., Johns Hopkins University
Beck, Alfred C., Rensselaer Polytechnic Institute
Bennett, Arthur J., McGill University
Berberich, Leo J., Johns Hopkins University
Bessey, Carlton E., Northeastern University
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Ohio University, Athens, Ohio	Clarence Kelch	Glen R. Smith	A. A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla	H. M. Horton	Lee Rogers	Edwin Kurtz
Oklahoma, University of, Norman, Okla	G. B. Brady	H. C. Mitschrich	F. G. Tappan
Oregon Agricultural College, Corvallis, Ore	F. D. Crowther	E. F. Reddy	F. O. McMillan
Pennsylvania State College, State College, Pa	F. F. Wilkins	C. C. Huggler	L. A. Doggett
Pennsylvania, University of, Philadelphia	F. H. Riordan, Jr.	W. H. Hamilton	C. D. Fawcett
Pittsburgh, University of, Pittsburgh, Pa	M. G. Jarrett	D. P. Mitchell	H. E. Dyche
Princeton University, Princeton, N. J	John Reine	J. M. Myers	Malcolm MacLaren
Purdue University, Lafayette, Ind	A. Howard	T. B. Holliday	A. N. Topping
Rensselaer Polytechnic Institute, Troy, N. Y	F. M. Sebast	W. C. Michels	F. M. Sebast
Rhode Island State College, Kingston, R. I	G. A. Eddy	C. F. Easterbrooks	Wm. Anderson
Rose Polytechnic Institute, Terre Haute, Ind	D. L. Fenner	W. F. A. Hammerling	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J	E. C. Siddons	W. H. Bohlke	F. F. Thompson
Santa Clara, University of, Santa Clara, Calif	Lloyd Whitwam	W. P. Fisher	D. W. Griswold
South Dakota State School of Mines, Rapid City, S. D	D. A. White	Harold Eade	J. O. Kammerman
South Dakota, University of, Vermillion, S. D	Stanley Boegler	L. E. Crowell	B. B. Brackett
Southern California, University of, Los Angeles, Calif	Gilbert Dunstan	Osborne Hatch	P. S. Biegler
Stanford University, Stanford University, Calif	A. V. Pering	J. G. Sharp	T. H. Morgan
Stevens Institute of Technology, Hoboken, N. J	D. B. Wesstrom	G. E. Witham	Frank C. Stockwell
Swarthmore College, Swarthmore, Pa	T. C. Lightfoot	W. F. Denkhaus	Lewis Fussell
Syracuse University, Syracuse, N. Y	G. F. Kern	T. P. Hall	C. W. Henderson
Tennessee, University of, Knoxville, Tenn	F. N. Green	B. M. Gallaher	Charles A. Perkins
Texas, A. & M. College of, College Station, Texas	C. A. Altenbern	J. L. Pratt	C. C. Yates
Texas, University of, Austin, Tex	A. L. Mayfield	H. W. Zuch	J. A. Correll
Utah, University of, Salt Lake City, Utah	J. I. Farrell	M. L. Hoag	J. F. Merrill
Virginia Military Institute, Lexington, Va	R. P. Williamson	M. L. Waring	S. W. Anderson
Virginia Polytechnic Institute, Blacksburg, Va	R. M. Hutcheson	M. B. Cogbill	Claudius Lee
Virginia, University of, University, Va	R. C. Small	H. M. Roth	W. S. Rodman
Washington, State College of, Pullman, Wash	Earl Munson	C. E. Peterson	R. D. Sloan
Washington University, St. Louis, Mo	E. B. Kempster, Jr.	R. L. Belshe	H. G. Hake
Washington, University of, Seattle, Wash	C. M. Murray, Jr.	Roy H. Crosby	George S. Smith
Washington and Lee University, Lexington, Va	C. M. Wood	R. E. Kepler	R. W. Dickey
West Virginia University, Morgantown, W. Va	I. L. Smith	P. E. Davis	A. H. Forman
Wisconsin, University of, Madison, Wis	Benj. Teare	N. B. Thayer	C. M. Jansky
Worcester Polytechnic Institute, Worcester, Mass	D. A. Calder	C. H. Kauke	H. A. Maxfield
Wyoming, University of, Laramie, Wyo	John Hicks	Edward Joslin	G. H. Sechrist
Yale University, New Haven, Conn	W. W. Parker	J. W. Hinkley	Charles F. Scott
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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Automatic Arc Welding.—Bulletin GEA 586, 12 pp. Describes the application of automatic arc welding equipment. General Electric Company, Schenectady, N. Y.

Graphic Instruments.—Catalog 406, 72 pp. Describes Esterline-Angus graphic instruments for power station and industrial application. Esterline-Angus Company, Indianapolis, Ind.

Therapeutic Carbons.—Bulletin. Gives a detailed description of a new line of carbons for use with arc lamps designed for therapeutic work. The National Carbon Company, Inc., Carbon Sales Division, Cleveland, O.

Magnet Wire.—Catalog 27. Describes a complete line of magnet wires. Contains numerous illustrations, tables and other data of assistance to those interested in the use of magnet wire. Maring Wire Company, Inc., Muskegon, Mich.

Pyrex in Industry.—Bulletin, 20 pp. Describes Pyrex industrial glass products. Among the more recent applications of Pyrex is in the manufacture of high-voltage line insulators. Corning Glass Works, Corning, N. Y.

Aluminum High Voltage Wires.—Bulletin, 20 pp. (in German). Describes the application of aluminum conductors for high voltage transmission lines in Germany and includes a map showing all German power systems of 30 kv. and upward. Vereinigte Aluminium-Werke, Akt., Lautawerk (Lausitz) Germany.

Magnet Wire Dereeler.—Bulletin 35, 10 pp. Describes the Chapman compensating, tensionless magnet wire dereeler. The device is an auxiliary piece of apparatus for use with any suitable winding machine or lathe. P. E. Chapman Electrical Works, 10th and Walnut Streets, St. Louis, Mo.

Relays.—Supplement 1 to Bulletin 550, 2 pp. Describes Roller-Smith Type FR relays. The principal application is in connection with contact-making instruments, meters and similar equipment wherein it is desired to have a small current operate devices requiring a relatively large current. Roller-Smith Company, 12 Park Place, New York.

NOTES OF THE INDUSTRY

The Burke Electric Company, Erie, Penn., have removed their Pittsburgh sales and service office to 2124 Farmers Bank Building. W. S. Wallace, who has been Pittsburgh sales manager, will continue in charge of this office.

The James R. Kearney Corporation, 4224 Clayton Avenue, St. Louis, Mo., announce that the J. E. Sumpter Company, Security Building, Minneapolis, have recently joined their sales organization. They will be in charge of sales in the states of North and South Dakota and parts of Wisconsin.

Hubbard & Company, Pittsburgh, announce that Joseph V. Smith, formerly general manager of the shovel division at Pittsburgh, has been appointed Pacific Coast manager for the Electric Materials Department of this company with headquarters at the Oakland, California, plant. Sales on the Pacific Coast will be made exclusively through the Hubbard coast distributors, Pacific States Electric Company and Graybar Electric Company, Inc.

Traveling Exhibition of Bakelite in Industry.—There is at present on tour, in the central states, a traveling exhibition of "Bakelite in Industry," and, according to the Bakelite Corporation, 247 Park Avenue, New York, the exhibition includes the products, employing Bakelite in some form, of some two hundred manufacturers throughout the United States. A folder entitled "A Caravan of Ideas" describes the unique tour.

New Oil Circuit-Breaker.—The Condit Electrical Manufacturing Corporation, Boston, has placed on the market a manually operated pole top oil circuit-breaker (Type PK-9,) especially designed for outdoor distribution for all voltages up to 7500. The breaker is furnished in one, two and three poles for 400, 600 and 800 ampere capacity at 7500 volts, with an estimated interrupting capacity of 3000 amperes at 7500 volts.

New Slack Puller.—The W. N. Matthews Corporation, 3700 Forest Park Boulevard, St. Louis, Mo., is marketing an improved quick release slack puller designed primarily for pulling slack from conductor and guy wires. It is extensively used by public utilities for changing disc insulators. The device occupies very little space and can be used safely in very restricted places. It is claimed that with the gear ratio supplied one man can pull as much strain with the slack puller as four men can by using a regular block and tackle. The improved equipment is obtainable in two sizes, one of 3000 pounds maximum and one of 10,000 pounds maximum.

Thomas Sales Conference.—During the week of March first, the sales and engineering conference of The R. Thomas & Sons Company, manufacturers of high tension porcelain insulators, was held at the home office in East Liverpool, Ohio. Those in attendance included J. E. Way, general sales manager, P. Maxwell, eastern sales manager, S. Snyder, export manager, R. H. Anthony, Boston manager, R. W. Harms, Chicago manager W. S. Whiteman, Atlanta, C. E. Remaly, Sandusky, H. J. Billica, Seattle and J. E. Crilly, San Francisco.

Dudlo Mfg. Corporation Expands. Due to a large increase in its business, the Dudlo Manufacturing Corporation, Fort Wayne, Indiana, manufacturers of magnet wire and coils have found it necessary to build many new enamel and cotton insulating machines. Equipment is also being installed for producing square and rectangular wire and flexible copper cables. A new conveyor system is in operation to accelerate the handling of materials through the various departments. The company recently completed a new wire mill devoted exclusively to the drawing and insulating of magnet wire. The eastern office is now located at 56 Earl Street, Newark, N. J., where a branch factory for winding coils is now operating in conjunction with the warehouse stock of wire.

The W. N. Matthews Corporation, St. Louis, Mo., manufacturers of electrical specialties and mechanical painting equipment, have made the following changes in their organization: J. B. Graves, 1106 East 38th Street, Minneapolis, has succeeded the J. E. Sumpter Company, as representative in the states of Minnesota, North and South Dakota and northern Wisconsin. Arthur E. Bacon, 1429 Eighteenth Street, Denver, has had the state of Utah added to his territory. He is the present representative in the states of Colorado, New Mexico, Wyoming and part of Nebraska. Arthur S. Hall has been added to the sales organization of the Boston office in charge of H. Van Rosen. Mr. Hall will make his headquarters at 98 Longfellow Road, Worcester, Mass.

The Timken Company Has Profitable Year.—The annual report of the Timken Roller Bearing Company, Canton, Ohio, for the year ending December 31, 1926, shows a net profit from sales, with other net income, of $8,474,103. Cash dividends were paid during the year to the amount of $5,403,969, and a balance of $3,045,120 was transferred to surplus account. The report shows that the sales of bearings to manufacturers of general industrial equipment were approximately double those of the previous year; also, that Timken bearings are now used extensively in some three hundred kinds of machinery. During 1926 three new types of bearings were introduced, including a line of double bearings, self-contained, for certain types of electric motors, turbines, pumps, etc. Also, the first large order for railroad passenger car bearings was obtained in the Fall of 1926 from the Chicago, Milwaukee and St. Paul Railroad, which involved the roller bearing equipment for twelve complete trains.